This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Bt. from Grafton & Co. [illegible]
[illegible]

£6.10.0
Cat 58
RAS

356

L.11 356

James Walker.

18662 d. 71

600025077R

BIBLIOTHECA BODLEIANA

DE

Abou

Sta

di

Abo

or

h

LIVERPOOL AND MANCHESTER RAILWAY.

REPORT

TO

THE DIRECTORS

ON THE COMPARATIVE MERITS

OF

LOCO-MOTIVE & FIXED ENGINES,

AS A MOVING POWER.

By JAMES WALKER, F.R.S. L. & E.
CIVIL ENGINEER.

SECOND EDITION, CORRECTED.

LONDON:
PUBLISHED BY JOHN AND ARTHUR ARCH, CORNHILL.

1829.

Printed by C. Baynes,
Duke-street, Lincoln's-inn-fields.

This Report was written in consequence of a communication from Henry Booth, Esq. Treasurer of the Liverpool and Manchester Railway Company, contained in a letter dated 18th November, 1828, from which the following is an extract.

" The time is arrived when the Directors deem it
" necessary to decide on the kind of moving power
" to be adopted on the Liverpool and Manchester
" Railway. Expecting, as they do, a very large
" traffic, perhaps to the extent of 2 or 3,000 tons
" per day, to be carried along the line, they have
" had little hesitation in determining that some
" more efficient power than horses must be used;
" but being aware that on the Railways in the North
" both Fixed Engines and Loco-motive Engines are
" employed, and that their respective merits and
" capabilities are variously estimated, they are
" anxious to obtain the most correct information on
" the subject; and with that view have determined

" to request the combined professional assistance " of a Civil Engineer and of an experienced maker " of Steam Engines; and I have accordingly been " instructed to write to you and to Mr. Rastrick of " Stourbridge, and to convey to you the request of " the Directors that you will undertake, on behalf " of this Company, a journey to Darlington and the " neighbourhood of Newcastle, to inspect the different Railways in those districts, and to ascertain, " by a thorough investigation into the power of the " Engines, the cost of working them, and their " actual performance, the comparative merits of the " two descriptions of moving power."

At a meeting of the Directors at Liverpool, on 12th January, 1829, the following instructions were also delivered:—

" Mr. Walker and Mr. Rastrick are requested, in the first place, to ascertain the comparative expense of conveying Goods on a Railway by Loco-motive Engines and by Fixed Engines.

" But, in addition to this primary object, there are other and very important considerations to be attended to.

" The state and condition of the Road where the different systems are in use, deserves particular regard; and especially how far any injury which may be done by the Loco-motive to other Roads, is likely to occur to the Liverpool and Manchester.

"The wear and tear of waggons is another point. The cost of repairs under this head, on the Darlington Railway, has been very great—partly, it is said, owing to the Loco-motive Engine. If this be correct, it is important to ascertain whether the evil admits of a *remedy*.

"The quantity of traffic for which it will be expedient to provide the *power of conveyance* may be estimated as follows :—

From Liverpool or towards Manchester.

Daily.	Gross weight, about tons.
1000 tons of goods and merchandize, exclusive of waggons, from Liverpool to Manchester	1500
500 tons cattle, sheep, pigs, &c. that is, the cattle will occupy the room of 500 tons of goods, and the difference in actual weight will not be great	750
This large quantity may not occur more than two or three days in the week, still it must be provided for, as the conveyance of cattle cannot be delayed.	
400 tons of coals, a distance of 12 to 15 miles, say from Kenyon to Manchester	600
800 empty coal waggons, a distance of 8 to 20 miles, say from Liverpool to Whiston, Rainhill and Newton	800
800 passengers from Liverpool to Manchester, occupying about 35 carriages	100
Gross weight towards Manchester....tons	3750

From Manchester or towards Liverpool.

Daily.	Gross weight, about tons.
500 tons of goods, lime, stone, &c. exclusive of waggons	750
800 empty waggons or stages, which will have brought cotton or other goods at 15 cwt. each, say	250
200 empty coal waggons, a distance of 12 to 15 miles, say from Manchester to Kenyon	200
1600 tons of coals, a distance of 8 to 20 miles, say from Newton or Whiston to Liverpool ..	2400
250 empty cattle carriages	250
800 passengers from Manchester to Liverpool, occupying about 35 carriages	100
Gross weight towards Liverpool ....tons	3950

" The Directors are unanimously of opinion, that it is essential to the interests of the concern that the public should be accommodated in every respect, in the best possible manner, so as to leave no room for complaint or dissatisfaction, not only in the direct conveyance from Liverpool to Manchester, but also in taking up and delivering goods or passengers on different parts of the line.

" With reference to the Loco-motive Engine, it will be important to ascertain at what speed it can travel with safety, and with a given pressure of steam, having regard to the *economy of fuel*, an item of expenditure which on either system must unavoidably be so large.

" If Fixed Engines are to be used, can effectual accommodation be afforded to the public, in the way of convenient access to the Railway, for taking up or setting down, branching into, or out of the line, at different parts of the way ?

" The comparative *safety*, also, of the two modes, is a point on which the fullest information, and most correct opinion are to be desired.

" Taking into accounts all the circumstances, both as respects *goods* and *passengers*, on the above scale, the goods requiring punctuality of conveyance, and the passengers requiring safety and expedition, can both goods and passengers be conveyed on the two lines of Road at present provided ; and if so, by which system of conveyance can the desired object be best attained ?

" It will appear by the section that there are three inclined planes between Liverpool and Manchester, *viz.*

One in the Tunnel,
One at Rainhill,
One at Sutton.

The two former *ascending*, and the latter *descending* towards Manchester; the plane in the Tunnel is 1,970 yards in length, having an inclination of 1 in 48; the other two, 1½ mile long each, being inclined in the ratio of 1 in 96.

"The opinion of Mr. Walker and Mr. Rastrick is requested as to the power of the Engines to be employed at these planes, and as to the best scheme of working them, so as to afford the greatest facility for the transit of the large traffic which must pass over them."

To the Directors of the Liverpool and Manchester Railway Company.

GENTLEMEN,

THE general question submitted for Mr. Rastrick's and my consideration may be shortly stated in these words:

" *What, under all circumstances, is the best description*
" *of moving power to be employed upon the Liverpool and*
" *Manchester Railway?*"

The comparative advantages of the different kinds of power applicable to Rail-roads generally is at the present time a very interesting question, the difficulty and importance of which, as a matter of science, are much increased by the magnitude of your concern, and by the various considerations necessary to be embraced and balanced previously to arriving at any decision that would be useful to you, or consistent with the confidence you have placed in us.

The paper that was handed to us when we attended your meeting at Liverpool, has proved to us that you are fully aware of the points to which I refer. I have endeavoured to view them without prejudice, being assured that as a short time must show the true merits of the various modes of conveyance as applicable to your case and to others, I should, as a professional man, but ill discharge my duty to you, or consult my own interest, by allowing my judgment to be warped from advising that course, which, from the best information I have been able to collect, it would be advantageous for you to follow. I may here also take leave to say of Mr. Rastrick, that in every thing connected with our inquiry, and the conclusions we have arrived at, I have seen nothing like prejudice for or against any particular system, beyond what arose from his minute attention to the merits of each, and from the result of a very laborious investigation.

Account of Journey.

It may be proper to give you, in a few sentences, an abstract of our proceedings, that you may know how our time has been occupied.

On the 10th January I arrived at Stourbridge, where I was joined by Mr. Rastrick; another reason for my going there being to see a loco-motive Engine, intended for America, which has just been completed by him, with some improvements and alterations I had not before seen.

On the 13th January, the day after we attended your meeting and received your particular instructions, we proceeded with Mr. Stephenson along the line of your Railway, and on the 14th arrived at Manchester. I think it unnecessary to occupy your time by any report on the progress of your great work, which must be well known to you, further than by remarking, that the works appear to be done in a very substantial manner, and that as respects the strength of the rails, the size of their supports, and the great pains taken in the cuttings and embankments to reduce the inequalities of level, the Liverpool and Manchester Railway is very superior indeed to any thing of the kind that has yet been done.

On the 15th Mr. Stephenson accompanied us to the Bolton Railway, lately executed under his direction.

The principal object of our survey there was a loco-motive Engine made by him upon what he considers the best principle of any he has yet constructed, and the report we have since received from Mr. Sinclair, clerk to the company, to which I shall afterwards have occasion to refer, proves the great power which the Engine is capable of exerting.

On the 16th we arrived at Leeds, Mr. Stephenson having previously left us. Here we examined Mr. Blenkinsop's Engine upon the Middleton Rail-road. We saw it make a journey with 38 waggons, each containing 45 cwt. of coals, which, considering the small size of the Engine, exceeded our expectations, as we were told that a part of the way is level. We therefore requested Mr. Blenkinsop to furnish us with further particulars of expense and performance, which he has kindly and gratuitously done, and has allowed an exact measurement and section of the way to be taken for our use.

The 17th, 18th, 19th and 20th January we passed at Darlington, and upon the Stockton and Darlington Railway. Here was the largest field for observation we had yet seen, there being several loco-motive Engines of different forms and power; horses also are employed upon the same part of the line. Towards the upper end of it there are two inclined planes with stationary Engines. We had therefore the opportunity of seeing various modes of working, and of collecting information, which was liberally given to us, and which was the more to be valued, as neither the very active and intelligent Directors whom we saw nor their Agents appeared to have any object in view, but to advance the prosperity and usefulness of their concern, and to extend the results of their experience for the information of others.

On the 21st we proceeded to Sunderland, and on this and the following day we examined the line of the Hetton Railway, upon the lower part of which the work was, until within a few years, done by loco-motive, but is now performed by stationary Engines upon the reciprocating principle; the middle part is a series of inclined planes worked by stationary Engines, and upon the mile and half nearest the pits the loco-motive power is still used. From the different Agents upon this Colliery, we received very freely every assistance they could afford us; Mr. Wood, the company's cashier, has, at our request, given us further details, and besides taking an accurate section of the whole road expressly for our use, has furnished us with an account of every particular of expense, and a detailed statement of the various powers and modes of working upon the line.

From Hetton we proceeded on the evening of the 22d to Newcastle, and we remained in that neighbourhood until the 29th. From the 23d till the 26th inclusive, we were employed in arranging the observations of the past week, and in meetings with Mr. Thompson, the Patentee of the reciprocating system by fixed Engines, and with Mr. Wood, the manager of the Killingworth Collieries and author of the well-known treatise upon Rail-roads, both of whom were disposed to forward the object of our inquiry; Mr. Thompson having also allowed us to extract from his private book the details of expense and of work done upon the Brunton and Shields Railway, with much valuable general information on the subject. Thus, although the fall of snow prevented our getting out until the 27th, our time was fully and I trust usefully employed. The whole of the 27th was occupied upon the survey of the Brunton and Shields Road, which was constructed by Mr. Thompson upon his patent plan. The merits of the general principle I shall of course have occasion to discuss hereafter, but with regard to neatness of execution, despatch, and methodical system and arrangement, there is not, I believe, any road at present in use to be compared to this.

The surveys and experiments at Killingworth, in which we were assisted by Mr. Wood, occupied the whole of the 28th, and on the 29th we left Newcastle.

It is but justice to say, that in every quarter where we applied information has been most liberally afforded us, and in some cases before the parties knew who we were or to what our inquiry tended. The Directors, Proprietors, and Agents upon all the Rail-roads which we have visited, have received us courteously, and not only allowed us to inspect their works, but have prepared and furnished us such documents and abstracts as we required: and what is more remarkable, we found but little of that prejudice and strong feeling in favour of one system, which leads to a display of the favourable features and a concealment of the disadvantages on the one side, with a corresponding partial view of the other.

From the time of my return home I have given my almost undivided attention to the subject, in drawing results from our experiments and from the information received while upon the survey.

Having made our separate calculations, Mr. Rastrick and myself met at Oxford on the 20th February, and remained there until the 24th, when we came to general conclusions, in which it was satisfactory to find that there was little or no difference of opinion:—had the time allowed we should either have remained together or met again, and I doubt not have signed the same Report; but knowing from you the importance of not longer delaying the delivery of our decision, we thought it better that each should at once transmit to you his opinion in his own words; and if there be any difference in the items of expense, it is to be ascribed to the consideration we have separately given the question since we separated:—I believe that such difference will be found but trifling.

Your instructions state "*The comparative expense of conveying goods upon a Railway by loco-motive and by fixed Engines,*" as the primary object of inquiry.

I shall therefore first consider this subject:—but previously to going into detail, it may be proper to state that certain data are absolutely necessary to form a basis for the comparison. If the quantity of goods be small or uncertain, it would require no calculation to determine that the loco-motive system is the cheaper, because by it you increase the power by an increase of the number of Engines, and can therefore always proportion the power to the demand, while upon the stationary system it is necessary first to form an estimate of the probable trade, and then at once to establish a line of Engines, Ropes, &c. from end to end, that shall be complete and fully equal to it. There is therefore in the loco-motive system an advantage in this respect, that the outlay of capital may at the first be much less than by the other system.

Trade on Line.

You have given us sufficient information to guide us in the extent of power to be provided.

The gross weight from Liverpool or towards Manchester is stated at .... 3750 tons,
And from Manchester or towards Liverpool 3950 „

In the former number are 400 tons of coals and 200 tons of waggons from Kenyon to Manchester, being nearly half the length of the line at the Manchester end, and 800 tons of empty waggons from Liverpool to Whiston, Rainhill and Newton, averaging about half the whole length at the Liverpool end. In the trade towards Liverpool are included 200 tons of empty waggons from Manchester to Kenyon, and 2400 tons of coals and coal-waggons from Newton or Whiston to Liverpool.

This trade is equal to about 2000 tons of goods, or 3000 tons gross, moved in each direction between Liverpool and Manchester daily, which quantity we have therefore taken for the basis of our calculations.

Excepting at Rainhill and Sutton, and at the Liverpool Tunnel, no part of the line rises more than 1 in 800, and as the quantities conveyed in each direction are nearly equal, the assistance received from gravity in the one direction is equal to the retardation caused by it in the other; we have therefore considered the whole line (with the two exceptions stated) as horizontal.

As the stationary system must be adopted in the Liverpool Tunnel, whatever may be done in the other parts of the line, we have entirely excluded it in forming the comparative estimate.

I shall now proceed with the Loco-motive Estimate.

Loco-motive Estimate.

Number and Cost of Engines.

We assumed the convenient power of each Engine to be 10 horses, including the power necessary to propel itself and its tender. The diameter of the wheels we took at 5 feet, and the strength of the steam in the boiler at from 40 to 50 lbs. per square inch.

The gross weight of this Engine, with its tender and water, we find to be 10½ tons.

While the Engine is in motion we suppose that its velocity should be 10 miles per hour, to enable it to average 9 miles between the two extreme points; and when the speed of coaches upon the roads is considered, we apprehend that the rate ought not to be less.

An Engine of the above description will be found, by referring to note A, to take 19½ tons gross at 10 miles per hour, or 13 tons of goods and 6½ tons of waggons, and its expense we estimate as follows:—

One Engine will cost	£550	0	0
But to have *five* Engines always in repair *six* will be necessary, or the capital requisite to provide an Engine always ready for work will be 1⅕ of one Engine,—add therefore ⅕ of £550	110	0	0
Together	660	0	0
For a tender, tank, &c. £50, and ⅕ of 50, being	60	0	0
Making the whole cost of one Engine at work	£720	0	0

Now the average durability of the Engine, when the work is considered, may be taken at 20 years, or at 12½ years purchase.

The annual charge for capital is therefore	£57	12	0			
Less £60 receivable for the old materials at the end of 20 years, which is in present money equal to.	1	16	0			
Leaving annual cost				55	16	0
Add for estimated annual repairs, as per note B				107	8	0
And for wages, coal, and other working expenses, as detailed in notes C. and D.				204	0	4
Making the annual cost of each Engine working 312 days				£367	4	4

We have now to ascertain the number of Engines that will be required.

We calculate that each Engine may work, exclusive of stoppages, from 9 to 10 hours per day, at 10 miles per hour, or it will make three journeys daily between Liverpool and Manchester, taking with it 13 tons of goods, which is the same as 1170 tons conveyed one mile.

The daily traffic being taken at 4000 tons conveyed 30 miles, or 120,000 tons conveyed one mile, will, according to this, require 102 Engines constantly at work.

Our first great item of expense is therefore 102 Engines at £367. 4s. 4d., amounting to £37,456. 2s.

Rainhill and Sutton Planes.

But in this we have allowed nothing for the additional power required at Rainhill and Sutton, the rise of which is 1 in 96. Our idea was that an additional Engine might be employed to assist the others at these planes, but a little consideration showed us our mistake. I am unwilling to confuse my report by introducing calculations into the context; but as it may be important that this point be well understood, I will state the principle in a familiar way. Our calculation of friction upon a level is $\frac{1}{180}$ of the weight moved; but the rise of Rainhill and Sutton being $\frac{1}{96}$, the resistance of gravity is nearly double that by friction. Accurately it is thus:—

2240 lbs. divided by 180 gives for friction of 1 ton.................................12.44 lbs.
2240 lbs. divided by 96 gives for gravity of 1 ton on rising 1 in 96....................23.33 lbs.

The whole resistance to 1 ton on Rainhill is therefore 35.77 lbs. or say 35¾ lbs.

And the resistance to 10½ tons, the weight of Engine, &c. is $375\frac{6}{10}$ lbs.

But the power of the Engine at 10 miles being (by Note A.) 375 lbs., it is evident that an Engine will just move its own weight up the hill at 10 miles per hour, and consequently an additional number of Engines could do no good, as the weight of each would be its load. Either therefore the power of the Engine must be increased, or the speed diminished, or some other plan be devised for the planes.

The objection to increasing the power is, that it would be forcing the Engine beyond its regular work, which it is desirable to avoid to so great an extent, for it would require two Engines, each 18 horses' power (see note E.), to raise themselves and 13 tons of goods up Rainhill at 10 miles per hour. Whatever may be done for a short length, or for an experiment intended to show what an Engine *can* do, I think it impossible to recommend such a system upon a road which is to unite the various advantages you state.

If again we reduce the speed, say to 5 miles per hour, we shall have half the Engine's power applicable to goods and carriages, the other half being required for its own weight and friction. (See note F.)

In this way, if we suppose the Engine, with 20 tons of goods and waggons, to arrive at the bottom of the planes from Liverpool or Manchester at the rate of 10 miles per hour, it will require another Engine of the same power to go up the plane at 5 miles per hour, and will occupy 18 minutes in ascending. Or, if 8 miles per hour be the standard of travelling, the Engine would then take 27 tons of goods and waggons upon the level (see note G), would require the assistance of another Engine of the same power to ascend the hill, with a speed of 4½ miles per hour (Note G 2), and would occupy 20 minutes in ascending.

It would consequently be doing an injury to the loco-motive system to apply it to this work, for which it is evidently unfit. However good it may be in itself, it has its limits, and an ascent of 1 in 96 is beyond them, where the length and requisite speed are so great.

We therefore had recourse to the stationary system as the assisting power to the loco-motives upon the planes,

and found that it would be necessary to have two Engines of 50 horses at each end of Rainhill to do the required work, and that the loco-motive Engines also should accompany their load up the hill to assist in taking down the rope, which we found the empty waggons alone could not do with the necessary speed. To give 9 miles clear per hour, the speed of the waggons while in motion upon the planes will require to be 12 miles per hour. The 1½ mile, that is, the length of the plane, will therefore
take .... 7½ minutes,
and the stoppage for changing, &c. .. .. 2½ minutes,

making .... 10 minutes,

or six journeys per hour, or if ten working hours, say 60 journeys per day; and 3000 tons being to be passed in each direction daily, the load for each journey will be 50 tons, goods and waggons, or say 52 tons, which will require the power stated. (See note H.)

Loco-motive Estimate.

Annual Expense.

We have now therefore to add the annual cost of the fixed Engines to the sum already stated for the loco-motives, viz. to £37,456 2 0

The expense of stationary Engines, with ropes, &c. as detailed in Note I. is per annum		5,013 6 0
Crossing upon level of way £120, of which the interest is		6 0 0
And for annual expenses of water-stations, as detailed in note K.		922 10 0
Duplicates of Engines	£400 0 0	
Duplicates of ropes, 18 tons 17 cwt. 16 lbs. at £51	961 14 3	
Signals	100 0 0	
	£1461 14 3	
Carried forward		£43,397 18 0

Brought forward	£43,397	18	0
This sum (£1461. 14s. 3d.) considered as a necessary additional capital for articles, of which the deterioration is already accounted for, makes at 5 per cent.	73	2	0
The interest of capital and annual expenses of the loco-motive system is therefore	£43,471	0	0

This sum is exclusive of the expense of working the Liverpool Tunnel, which (as was premised) is supposed not to be affected by the plan that may be thought most desirable upon the line generally, and exclusive also of the wear of rails by the Engines travelling upon them.

To reduce this to a rate per ton per mile, we have 4000 tons moved 30 miles per day for 312 days, or 37,440,000 tons moved one mile for £43,471, which is at the rate of .2787, or about $\frac{7}{25}$ of a penny per ton per mile.

Capital requisite.

As the amount of capital necessary under each system is also a proper subject for consideration, I shall, before proceeding to the stationary, state the sum requisite upon the loco-motive plan:—

It comprises 123 Engines & tenders, at £600,	£73,800	0	0
Engines for Rainhill & Sutton (see note I.)	9,190	0	0
Duplicates for same and machinery, as above	400	0	0
Ropes for Rainhill, deducting old (see note I.)............................	792	0	0
Duplicate ropes, as above	961	14	3
Cost of iron crossings	120	0	0
Signals for Rainhill and Sutton..........	100	0	0
Ten water-stations at £560, (see note K.).	5,600	0	0
So that the requisite capital is....	£90,963	14	3

The expense of the stationary system comes next to be estimated.

Stationary Estimate.

Number and cost of Engines.

Preparatory to this we considered the space between the Liverpool Tunnel and the foot of Rainhill plane, about 6 miles in length, to be divided into 4 spaces, each 1½ mile long; the ascending and descending planes each to form one stage; the 2 miles level upon Rainhill two stages, and the 19 miles, from the foot of the plane to Manchester, to be divided into 12 stages of 1½ mile each, and one stage of one mile nearest to Manchester. The speed of the waggons, while in motion, we supposed 12 miles per hour; consequently the 1½ mile stages would be performed in 7½ minutes, and if 2½ minutes be allowed for stoppages and changing ropes, the rate from one extremity of the line to the other would be 9 miles per hour, which, when allowance is made for taking water, coals, &c., is about the clear rate at which we have estimated the loco-motive Engines. We have supposed the reciprocating plan upon the principle of the Brunton and Shields way to be adopted, and that the weight of the goods and waggons forming the train is 52 tons, as we before calculated for the inclined planes.

The power to be applied to move this weight upon the level will be 26 horses in each direction;—this we calculated at 30 horses, making thus two 30-horse Engines at each end of the mile and half stages. (See note L.)

The calculation upon the loco-motive system showed that two 50-horse Engines at each end were sufficient to work the Rainhill and Sutton inclined planes; but as the Engines will now, in addition, have to draw the waggons towards them for a mile upon the level, an increase of 10 horses' power has been made to each Engine, making two 60-horse Engines to each station.

An additional power of 30 horses to the Engines at the head of the Liverpool Tunnel also is applied to draw the waggons towards it, and two 12-horse Engines are calculated for the Manchester end, the work of both extremes being in one direction only.

From the descent of the Rainhill planes, and the two stages upon the hill being only one mile long, two Engines of 20 horses each are sufficient in these situations.

The estimate of the two 12-horse Engines at the Manchester end is (per note M.)	£1725	0	0
Fifteen stations with two 30-horse Engines at each, at £3500 (per note N.)........	52,500	0	0
Upon Rainhill and at the foot of the planes, three stations each with two 20-horse Engines, at £2710 (per note O.) .	8130	0	0
At the top of the two planes two 60-horse Engines to each (per note P.)	10,000	0	0
At the top of the Liverpool Tunnel 30 horses additional power..............	2000	0	0
Amounting to	74,355	0	0
Pullies for two lines, each 29¾ miles long 8 yards distant, No. 13,090 at 15s. including fittings......................	9817	10	0
Extras to foundations of Engines and Engine-houses in Chat Moss	3000	0	0
Making capital for Engines......	£87,172	10	0

Stationary Estimate.
Annual Expense.

Interest at 5 per cent, and depreciation at 1½ per cent. on capital of Engines and Buildings as estimated, or 6½ per cent. in all upon £87,172. 10s.........	£5,666	4	3
Repairs, Coals, and working expenses (see note Q.)	11,257	15	8
Carried forward	£16,923	19	11

Brought forward....	£16,923	19	11
Rope at $\frac{8}{100}$ of a penny per ton per mile, upon 4,000 tons conveyed 27 miles per day, for 312 days....................	11,232	0	0
Ropes for Rainhill and Sutton inclines (same as upon loco-motive system, detailed in note I.)....................	3,315	12	0
Rope for tail-rope on Rainhill and Sutton planes, at $\frac{8}{100}$ of a penny per ton per mile, upon 400 tons conveyed 3 miles per day, for 312 days..................	312	0	0
Spare rope—interest upon value (see note R.)	219	15	0
Sundry other expenses and charges as detailed in note S..................	1,291	4	6
Making the total of working the stationary Engines, with interest upon capital.	£33,294	11	5

This sum divided by the number of tons, as in the loco-motive system, makes the rate per ton per mile .2134 of a penny.

The capital employed in this case will be as follows:— Capital requisite.

Engines as above......................	£87,172	10	0
Duplicates for same (see note S.)	1,354	0	0
Ropes £4,395 (see note R.) and £792 (see note I.)	5,187	0	0
Cast-iron crossings.....................	300	0	0
Store ropes £5,336. 16s. 8d. (see note R.) and £961. 14s. 3d. (per loco-motive estimate above)	6,298	11	0
Signals............................	550	0	0
Making total comparative capital	£100,862	1	0

Comparison of Estimates.

To bring the whole under one view, I shall here state the results together.

The capital necessary for the various articles stated for the loco-motive system is	£90,963	14	3
And for the stationary	100,862	1	0
Difference in favour of the loco-motive plan	£9,898	6	9

The interest of capital and annual expense of the loco-motive system is	£43,471	0	0
And of the stationary	33,294	11	5
Leaving a difference in favour of the stationary plan of	£10,176	8	7

The rate per ton per mile upon the loco-motive principle is	.2787 of a penny.
And upon the stationary plan	.2134 of a penny.
Making an excess of expense per ton per mile of	.0653 of a penny,

by the loco-motive system, or the comparison of annual expenses is nearly as 7 to 9 in favour of the stationary system.

It is proper here to observe, that as the object of our labours was chiefly a comparative estimate, we have not included any general superintendence or contingent expenses, as these are supposed to be equal upon both principles; nor have I thought it necessary to calculate for the greater trade at the Liverpool end requiring a greater power of stationary Engines than that at the Manchester end, as this does not affect the aggregate expense. The allotment of power would have made the reports still more complex, and although this will be an important consideration previously to resolving on the power of each particular Engine, the *average* appeared sufficient for our present purpose.

Opinions as to result.

Having thus brought the question of expense to a point, I can readily anticipate a difference of opinion as to the correctness of the result from those who may have previously arrived at different conclusions, and may therefore have been led to prefer the one system as being much cheaper than the other.

The principal points of difference are likely to be :—

First—As to the quantity of work which the loco-motives are capable of performing.

Second—As to their consumption of fuel.

Third—As to the repairs they may require.

Fourth—As to the friction of the ropes used in the stationary system.

Fifth—As to the expense of ropes per ton of goods conveyed.

I shall therefore state generally the reasons for our conclusions on each of these points.

Power of Loco-motives.

First—As to the power of the loco-motive Engines.

We have calculated them at 10 horses, including the power for moving their own weight, which employs nearly the exertion of one horse's strength when going at the rate of 2½ miles per hour, and therefore reduces the *effective* or *disposable* power to 9 horses. We consider it more accurate thus to state the power of the Engine, the proportion of it necessary for propelling the machine varying with every degree of speed and inclination, until the dead weight requires the whole exertion of the moving power to draw it along, as we found to be the case upon the Rainhill and Sutton planes at 10 miles per hour. Now as it has for the last fifty years been agreed in expressing the power of a steam Engine by *horses' power*, to take the power of one horse at 33,000 lbs. raised one foot high, or 150 lbs. raised 220 feet high, in a minute, or at the rate of 2½ miles per hour, there can be no misapprehension as to what the power of a 10-horse Engine is. And it is almost as well agreed that the resistance of a well-constructed Edge Railway is upon a level $\frac{1}{180}$ of the weight moved, or about 12½ lbs. to the ton. The effect of gravity in moving upon inclined planes is still more universally agreed, and is an abstract question altogether independent of experiment. On all these points, therefore, there can be but little difference. But it may be said that a more powerful Engine can be used. It may so, and probably a 12 or 13-horse Engine, upon six wheels, may be found to suit better; but if the cost and weight of the machine and its carriage, and the consumption of fuel be increased in the proportion of the power (and this I deem requisite), no advantage, so far as respects the calculation, will be obtained. The limit is the size of the boiler, the cylinders of the Engines being generally capable of doing more, if the boilers would supply the steam. The best criterion is *experience*, and in referring to the Engines now in use, the most accurate test is, *not* what they can do for a short time in an experiment, but what they really do in their regular work. We therefore brought into a tabular form (see note T.) the result of the information we had respecting some of the Engines on the Darlington way—one, which is very powerful and weighty, constructed by Timothy Hackworth, the machinist upon the line—the others, I believe, made by Mr. Stephenson of Newcastle. It was stated to us that the summer work of Hackworth's Engine is 24 empty waggons from Stockton towards the pits at 5½ miles per hour, and the winter work 20 waggons at the same speed; the other smaller Engines take 20 waggons in summer and 16 in winter, at 5 miles per hour. By reducing the work to a level, the former at the rate of 10 miles per hour, appears by the table to draw of goods only,

in summer .... 17¾ tons,
in winter .... 14¾ tons;

The average being therefore.... 16¼ tons.

The smaller Engines, in the same way, do what upon a level would be equal to,

in summer .... 13⅓ tons,
in winter .... 10⅓ tons;

Making an average of.......... 12 tons nearly.

Now this is with their *ascending* train of empty waggons, which is the heaviest work they have to do, owing to the descent of the way with the loaded waggons; they consequently do this work only half the time. But the basis of our calculation is 13 tons of goods conveyed, summer and winter, in both directions, which therefore is more than any of the Darlington Engines, excepting Hackworth's. In the table, the work of the Engines is compared also at the speeds of 5 and 8 miles per hour.

The result of an experiment we made with a very good Engine at Killingworth proved that, for a short ascending length, it did nearly the work of 13 horses; but this was followed by an inclination in the opposite direction, in which its work was $7\frac{1}{4}$ horses; upon a level of about a mile, where the way was very much out of repair, it did nearly 11 horses. The Engine was, I think, travelling beyond its average speed, as is usually the case when experiments are being made; but even at this last work it would only carry 16 tons of goods at 10 miles per hour. The Engine was stated to be of 8 horses' power, exclusive of its own weight, say gross power 9 horses, and I believe this to be what it is fairly capable of doing.

Mr. Sinclair's detail of an experiment with the new Engine upon the Bolton way, when with 13 chaldron waggons, each about 73 cwt. it travelled for $1\frac{1}{5}$ mile at $8\frac{8}{10}$ miles per hour upon a rise of 1 in 432, makes the power to have been upon that occasion nearly 24 horses. Were this to be taken as the work which the engine is capable of continuing, it would (see note U.) take 41 tons of goods upon the Liverpool way at 10 miles per hour; but no one estimates the power of the engine at 24 horses, so it is impossible to calculate upon the above as a basis for your work. In the same letter Mr. Sinclair states, that the engine usually takes 7 or 8 waggons, "that number being most convenient," at 6 miles per hour: taking *eight* as the number, this would (see note V.) be the work of an 11-horse Engine, and upon your way is equal to $15\frac{1}{3}$ tons of goods at 10 miles per hour, which I apprehended to be the *practical*, *fair*, *every-day* work of the Engine, and all beyond this is of value only to show how much the Engine *can* do, just as a horse may be made, for a short space, to do twice the work he is capable of continuing without injury. As there is no *lock-up* safety-valve to this Engine, and as the valve is fixed down while the Engine is in motion, it was, I presume, impossible to ascertain the strength of the steam at the time of the experiment to which I have referred.

Mr. Robert Stephenson has reported to us an experiment with Hackworth's Engine, which I prefer, because that Engine has a safety-valve, which, although not quite out of the power of the Engine-man, is stated by Mr. S. to have been at liberty at the time.

It appears by this experiment, that the Engine took $48\frac{3}{4}$ tons of goods 2500 yards, upon a rise of 10 feet in a mile, and returned down, being equal to 5000 yards upon a level, at the rate of $11\frac{9}{10}$ miles per hour, and that the steam was blowing off when the experiment concluded.

I state the preceding as it has been given to us—Hackworth's Engine is undoubtedly the most powerful that has yet been made, as the amount of the tons conveyed by it, compared with the other Engines, proves:—the boiler is longer, with a returned or double flue; there are six wheels, and the weight is increased nearly in the proportion of the power. Mr. Stephenson's report states the consumption of coals to have been $1\frac{6}{10}$ lbs. per ton per mile, which is less than the average of former results, and probably the steam may have been lowered during the experiment, which being for so short a time (about a quarter of an hour) is not better evidence than the regular work of the Engine which has been detailed,—and as the Engine-men are paid per ton for the work they do with the Company's Engines, there is reason to conclude that they work them to the best advantage.

I have reasoned upon the Engines generally in their present state, but it is proper to say that improvements have, since my survey in 1824, been made in them, and that the attention at present bestowed upon the subject will in all probability still do much for them. The Engine made by Mr. Rastrick is different from that by Mr. Hackworth in the form of the flue and otherwise; Mr. Stephenson's is different from both, and every new Engine he makes, differs in some respects from the one preceding it.—Since 1824 the diameter of the wheels has been increased, wrought iron *tire* substituted for cast, spring safety-valves have been introduced, and the Engine itself is supported upon a spring carriage. I think all these decided and great improvements, and in estimating the question generally it is fair to anticipate others. It is true that improvements in the stationary system may also be expected, but not, I should say, to the same extent.

From the account of work by the Hetton Engines we find that they are doing less than the others, owing, as we have calculated, to the rise in one part of their journey being too great for their advantageous application. By the detail (see note W.) it will be seen that the work of those Engines is upon the Liverpool way equal to only 10 tons of goods at 10 miles per hour.

The slope of the Middleton road is well adapted for loco-motive Engines, descending loaded and ascending empty the average fall being 1 in 440, which makes the load in each direction very nearly the same. Mr. Blenkinsop rates his Engine at 6 horses, and by calculation we find that the work done while in motion, with 30 waggons, is 6½ horses descending and 6$\frac{1}{11}$ horses ascending.

Upon the whole, therefore, I am satisfied that the work we have stated for the Engines is as great as ought fairly to be calculated upon,—and I have gone the more into detail that you might be in possession of the principal facts upon which our calculations are founded.

I think it unnecessary to say more respecting the slipping of the wheels, than that it does not appear to form any ground of objection upon your line, when the weight to be taken is considered. The liability to slip is much lessened by the introduction of spring carriages for the Engines. By an experiment we made upon a very irregular part of the Killingworth line it was satisfactorily proved, that with 48 tons of goods and waggons there was no slipping.

Second—As to the consumption of fuel by loco-motive Engines.

Consumption of Fuel.

This article is so cheap in most places where loco-motive Engines are in use, that it is not customary to keep any accurate accounts of it, and the objections to a short experiment are evident.

The average of the experiments made at Hetton and Killingworth in January, 1825, gave for one ton of goods conveyed 1 mile upon a level at 4¼ miles per hour	2.15 lbs.
Mr. Blenkinsop's account at first made the quantity about 4 lbs., but an explanation since, confirmed by the statement of the Engine-man, reduces the consumption to..	2.70 „
The Hetton account of the present Engines, reduced to a level at about 4 miles per hour, is upwards of	3.00 „
The Hetton account of the Engines when upon the line near Sunderland is	2.00 „
Mr. R. Stephenson's report of the experiment upon the Darlington line, already referred to, at 11 miles per hour	1.60 „

But the account most to be depended upon from the length of time, and the accuracy with which, from its object, we may suppose it was kept, is that which has been furnished to us by Mr. Storey, Surveyor of the Darlington and Stockton line. The Company's view was to ascertain, without the knowledge of the Engine-men, the *actual* consumption of fuel, in the use of which (knowing that the men *pay*, as was before remarked, for the coals they burn) we may reasonably infer that they study economy.

It appears that 298 tons of coals were used by the four

Engines during the months of May and June, 1827, and that the work done in that time was equal to 249,239 tons of coal conveyed one mile upon the way. This is equal to 2.16 lbs. of coal per ton per mile, but as the coal was also employed to bring back the empty waggons, it became necessary to reduce the inclination to a level, and to suppose the Engines to have done work in both directions, which we did, and the result gave 2.8 lbs. of coals per ton of goods per mile. These quantities do not include the fuel required for heating the water at the water stations, and generally it is coal of a quality superior to that which will be used upon the Liverpool road, but the quantity is nearly six times what is necessary for a fixed Engine of the same power. As however the improvements in Mr. Rastrick's and Mr. Hackworth's boilers, to which I have already referred, will cause a saving of fuel, and as Mr. Stephenson's attention is at present directed to the same important subject, we may confidently expect that a reduction of expense on this point will be effected. We therefore fixed upon 2¼ lbs. per mile (which may be equal to about 2 lbs. of Newcastle coal), and our calculations are formed upon this standard.

Annual cost of Loco-motives.

Third—As to the *annual cost* of loco-motive Engines.

Any difference of opinion on this point is likely to be confined to the quantum of repair; for as to the original cost and men's wages in working them there can be but little ground for speculation. On the other heads we have formed our own judgment, and we find that the details furnished by Mr. Wood of Hetton and by Mr. Blenkinsop, are both above our estimate; but in this, as in other points, experience will induce a saving. I may instance the use of wrought-iron tire, as well as the great difference in the quality of this metal: one set of tire had worn out in ten weeks upon the Darlington way, while upon the Killingworth the Engine with which our experiments were made, had a tire which had been twelve months in use, and the effect was scarcely perceptible.

We have supposed that of *six* Engines *five* may be considered as always at work and the sixth under repair, which I do not think is by any means overstating the number necessary.

Friction of Ropes.

Fourth—As to the *friction of the ropes* in the stationary system.

Upon this we had some difficulty in obtaining satisfactory data. The friction of a wheel carriage upon a Railroad we have taken at $\frac{1}{180}$ of its weight; but in the present case the number of sheaves to be moved compared with the weight, the irregular surface of the rope, its rigidity or stiffness in winding upon the barrels, and the friction of the drums themselves, make the aggregate of resistance much greater.

If the rope be taken at per yard	4	lbs.
A second length of rope upon the drums will be also	4	„
The drums themselves will be equal to	2.6	„
And the pulleys to	4	„
Making the total weight per yard	14.6	lbs.

If the friction therefore be taken at $\frac{1}{180}$ of the mass in motion, it will be about $\frac{1}{50}$ of the weight of rope, taking the rope in one direction only or at 4 lbs. per yard ($180 \times 4 \div 14.6 = 50$.)

The results upon the Brunton and Shields way are very different from each other—In some the estimated power of the Engine is not sufficient to take the load independent of the rope, while in others it leaves a large surplus:—where the former is the case, it is evident that the Engine's power has been under-rated, which we found it generally to be on this line. In two of the planes where empty waggons are taken by gravity, we found (see note X.) the friction of the rope, as nearly as possible, $\frac{1}{22}$ of its weight. These, I think, good data.

Mr. R. Stephenson has reported an experiment upon the Darlington road, by which the friction was $\frac{1}{10}$ of the weight. This was also with the empty descending waggons.

Mr. Thompson's own idea is much under any of the above results.

I think that $\frac{1}{22}$ of the weight of the rope, in one direction, may be taken for its friction, and that of the drums, sheaves, &c.; and if to this be added $\frac{1}{180}$ of the other length of the rope, the result will not be far from the truth, and the strength of the Engines is calculated to be quite equal to this.

Cost of Ropes.

Fifth—As to the *cost of ropes.*

This being a most important item in the fixed system has occupied much of our attention, affecting as it does very materially the relative economy of the two systems. It will be seen by reference to the annual charge that ropes alone amount to upwards of £11,000 per annum, or about one-third of the whole expense.

Upon this subject experience of course is the only guide, and Mr. Thompson's experience is by far the greatest upon the reciprocating system. From an account kept by him, apparently with great accuracy of detail,

" the mean average cost of ropes has been found to be $\frac{51}{1000}$ of a penny," or $\frac{1}{20}$ of a penny nearly. The declination of the way being in the direction of the loaded waggons, and there being in some cases no *tail-rope*, are both favourable to this line as compared with a horizontal road; but as here the waggons are drawn back empty, the cost per ton of goods, as compared with the Liverpool and Manchester line, is increased.

Mr. Story reported to us, that the ropes upon the Brusselton inclined planes cost, by an account kept by him, one farthing per ton upon all the coal conveyed over them. We have by calculation reduced this to a horizontal surface, and find that it would be $\frac{23}{1000}$, or under $\frac{1}{40}$ of a penny per ton of goods per mile, exclusive of the wear of *tail-rope*. (See note Y.)

The reciprocating system being applied on the lower part of the Hetton road, Mr. Wood has informed us, that 301,800 tons of coal were conveyed over a distance of 2½ miles for an expense of £780 in ropes. By reducing this to a level, and to suit our case, we find the cost to be $\frac{13}{100}$ of a penny per ton per mile, which very much exceeds either of the former results. We believe the Coal company pay a price per ton to the rope-maker upon the quantity of goods conveyed.

After fully considering this important subject, in all its bearings, we fixed upon $\frac{8}{100}$ of a penny per ton of goods per mile, dividing it into $\frac{6}{100}$ for the head-rope and $\frac{2}{100}$ for the tail-rope.

In a matter of so great consequence I have thought it proper to be thus particular, at the risk of being tedious; and having now discussed what you very properly call the " primary object," I proceed to the investigation of the other subjects referred to in your instructions to us.

Injury to Way.

You enquire,—" *How far the injury which may be done " by loco-motive Engines is likely to occur to the Liver- " pool and Manchester Rail-road?*"

My opinion is, that the injury to other ways arises chiefly from the want of sufficient weight in the rails, from the blocks being too small, and from imperfect foundations, but that as great care appears to have been taken to guard against these evils upon your line, there is no injury in the way of breaking or bending to be apprehended, unless perhaps on Chat Moss, or upon the embankments formed of the moss or other soft material, and that will be only until the foundations become consolidated. This opinion is of course given with limitation as to the weight of the Engine and water in the boiler, which we have calculated as not exceeding 8 tons. If an Engine like Hackwork's or Mr. Stephenson's heavy one be used, we conclude it will have six wheels like them.

It is proper also to state, that the loco-motive Engine has to be debited with the wear of the rails in even a greater proportion to its weight than the goods and waggons, owing to the greater load upon the wheels, and the vibration caused by the working of the Engine. In the account of annual expense no sum has been charged for any wear of the Railway.

Wear and Tear of Waggons.

" *The wear and tear of waggons*" is the next point to which you refer, and on this I cannot do better than quote from Mr. Storey's letter on the subject, especially as it is the Darlington waggons you state to have suffered so much.

" The destruction of the waggons," says Mr. Storey, " (for it is not wear) occasioned by the Engines, compared

" with that by horses, is much more by the former than by
" the latter. The principal parts damaged are the bot-
" tom framing and axles. The cause I conceive to be the
" sudden jerks at starting and stopping, the frequency of
" one, two, or even three waggons getting off the way at
" the turn-outs or pass-byes, and their being trailed a
" considerable distance before the Engine-man sees it, or
" the Engine feels it so perceptibly as to inform the man
" that she has something more to do; and also when pass-
" ing the sidings very frequently the switches get de-
" ranged; the Engine going from 6 to 8 miles per hour,
" the waggons are thrown out of their proper direction,
" when a twist takes place on the waggon framing, and
" with the sudden stopping of such a train at that
" speed, causes very great destruction to every part of the
" waggon."

It may be added to Mr. Storey's observations, that as the speed with Engines is greater than with horses, the injury is also greater in case of any irregularity. The curves upon ways are also injurious to waggons by the greater friction they occasion. From the Darlington line falling in the direction of the load, the momentum of the loaded waggons tends to increase the damage, in case of any accident upon that part of the line.

The straightness of your line, the strength of the rails, and the way being nearly level, except at the inclined planes, are all favourable for the waggons, when compared with the Darlington. Indeed I think that almost the only probable cause of injury to the waggons with you will arise from the sudden stoppages; but this may be much lessened by the introduction of a bent iron acting as a spring at the end of the waggon, to ease the effects of blows from the concussion with the other waggon before and behind.

Accommodation to Public.

As respects the "*accommodation to the public*,"

Our opinion is, that it may be given by either system, so as to leave no reasonable ground for complaint or dissatisfaction, either in the direct conveyance from end to end, or in the taking up or delivering of goods and passengers at the intermediate places.

Each system has its peculiar advantages.

By the loco-motive the train may be stopped at pleasure; but as the grand object will be despatch between the extreme points, the stoppings should be at the fixed stations only, where goods could be delivered, and passengers set down. In the loco-motive plan, this would be done by sidings at proper distances, and this system has the advantage, that the stopping of any single train might be longer or shorter without detention to the general traffic.

Upon the stationary system there would be sidings also, where carriages and waggons might draw off, and when ready to start again they would return to the main line; but being there, they must proceed at the uniform speed, for as there would be a general *sympathy* throughout the whole line, the stoppage or delay at any point would affect the whole. This is a disadvantage of the stationary system.

The probability of accident upon any particular part of the system is, I think, less with the stationary than with the loco-motive; but in the former the effects of an accident extend to the whole line, whereas in the latter they are confined to the particular Engine and its train, unless they happen to obstruct the way and prevent others from passing. The one system is like a number of short unconnected chains, the other resembles a chain extending from Liverpool to Manchester, the failure of one link of which would derange the whole.

The loco-motive Engines would follow each other at the average interval of about 4 minutes, and at two-thirds of a mile distance.

It will require some exertion to methodize the stationary system, and some experience to work it properly, but the knowledge that it is necessary to be regular and careful will produce a corresponding anxiety and attention in all concerned, and in time the operation will become almost mechanical. There are about twenty changes of horses in the mail between London and Liverpool, a stoppage at any one of which influences the whole; reverting to our metaphor, the chain here extends for two hundred miles, and notwithstanding the various chances of accidents and delays the mail generally arrives about the proper time.

The most probable cause of delay will be from the ropes breaking. It is rather remarkable, that when we were upon the Hetton way, one of the ropes broke in two places, I believe through carelessness, and delayed the train about an hour. Also while we were upon the Brunton way some delay in the descending took place through a few of the waggons getting off the road, a switch having been left in the wrong direction.

The stoppage of 2½ minutes at each stage for changing the ropes will give an opportunity for passengers and waggons to join, if the load be not already complete. The waggons going in opposite directions will meet at the stations, and by the proposed method there will be no delay but for the two minutes and a half. This can be effected by the trains crossing from the one line to the other at each station* (as shown by the diagram), by which both lines of road will always be occupied, and each Engine always drawing two trains, one in each direction, towards it, while in the meantime the two other ropes belonging to the same Engine will be going out as tail-ropes to the two trains that are moving in each direction from it. The journey from Liverpool to Manchester will thus be made in three hours and a half with both goods and passengers. As the stations are a mile and a half apart, the greatest distance to a station can never exceed three quarters of a mile.

---

* In his report, Mr. Rastrick states that the plan of crossing was struck out by him, which is correct.

If the *switches* or *tongues* of the rails be made with springs, they will act without any interference or care from the attendants being necessary. This will remove in a great degree the evil of crossings, and there being two barrels over each line of way, the motion of the Engine need never be changed.

As the mechanism of this is not easily expressed so as to be intelligible either in words or by a drawing, I have ordered a model to be made, which will, I think, answer the purpose better.

The crossing of roads upon the level of the Railway is more objectionable with the stationary than with the locomotive system. Had the plan been fixed before the levels were formed, this might probably have in many instances been avoided, by making more of the crossings *over* or sinking them *under* the level of the Railway, and with some it may not be too late even now. Mr. Locke has reported to us thirty roads (chiefly for accommodation) upon the level of the Railway in the whole line.

By the Engines working with what are technically called *friction clutches*, or with *friction drums* (by which, in case of stoppage, the Engine goes on without carrying the rope-drum along with it), by having careful men to accompany the trains with powerful brakes, by connecting the head and tail ropes together under the train, by a contrivance instantly to disengage the train from the rope, and by proper signals of approach, any chance of accident to persons or cattle crossing would be very much lessened; but as the loco-motive Engines can be backed, and the waggons consequently stopped more expeditiously, they are so far safer in this respect.

You inquire particularly as to the "*comparative safety* "*of the two modes.*" Safety.

As a general answer I should say that the stationary is the safer, chiefly from the loco-motives being necessarily high pressure Engines, and accompanying the goods or passengers upon the way. I see no reason for changing the opinion I gave you in 1824 of the impropriety of fixing down the safety-valve, without having a lock-up valve out of the Engine-man's power. Within the last year two accidents occurred upon the Darlington way, in each of which a life was lost, and in both cases the safety-valve was fixed down. The Darlington Engines have since had additional spring safety-valves attached to them, by which the danger is much diminished; and Mr. Rastrick has to his Engine fitted an ingenious spring safety-valve, completely beyond the reach of the workman, which will, I doubt not, answer an excellent purpose. In your case, they would be indispensable, for any accident at the outset, attended with loss of life or limb, would seriously prejudice the concern with the public.

All the accidents that I have heard of have happened through the fire-tube bursting, and the steam blowing out the fire-bars, the hot water, &c. at the fire-door. Should you adopt the loco-motive system, the fire-tube should be returned in the boiler, as in Hackworth's Engine, so that the fire-place be in the end of the boiler, farther from the train. By these and the other means commonly in use, and by the careful and frequent examination of the tubes, I think there could be but little danger, as respects passengers or goods, to be feared—certainly not so much as to be a sufficient reason for not adopting the loco-motive system, if in other respects it be thought preferable.

I cannot, however, go so far as to say that there is no more danger with *high* than with *low* pressure Engines; for although it may be true, that if the boiler be made of strength proportioned to the pressure, a failure in the one description is as likely as in the other, yet the effects of such an accident with a high pressure boiler are naturally much more terrible than with a low pressure—the one may be called an *explosion*, often destroying all around it—the other is generally confined to tearing the boiler, extinguishing the fire, and perhaps scalding the attendant, if close to the place.

In using the general expression "*high pressure*," I here refer to such a pressure as is necessary for loco-motive Engines. Upon the Brunton and Shields way the Engines are high pressure, but only about half the pressure of the loco-motives.

General conclusion.

Your next inquiry is, "*Whether goods and passengers* "*can be conveyed upon the two lines already provided, and* "*if so, by what system the desired object can be best at-* "*tained?*"

My opinion is, that with communications between the two lines, and branches from them at proper distances, the objects contemplated can be attained; but that with *two* lines, the stationary system will, upon the whole, be the preferable, as the trains will always meet at the stations, and as there will consequently be no occasion for any turns out or breaks in the line, except at these places.

With the loco-motive, a third line would be a great advantage, as the Engines might then pass each other, if going at different speeds, or in case of any stoppage or accident upon either of the main lines.

> Upon the consideration of the question in every point of view, taking the two lines of road as now forming, and having reference to *economy*, *despatch*, *safety* and *convenience*, our opinion is, that if it be resolved to make the Liverpool and Manchester Railway complete at once, so as to accommodate the traffic stated in your instructions, or a quantity approaching to it, the *stationary reciprocating* system is the *best;* but that if any circumstances should induce you to proceed by degrees and to proportion the power of conveyance to the demand, then we recommend *loco-motive* Engines upon the line generally, and *two fixed* Engines upon *Rainhill* and *Sutton* planes, to draw up the loco-motive Engines, as well as the goods and carriages.

Should the latter plan be adopted, you would of course only order such a number of Engines as you might see occasion for, both on account of saving expense, and to enable you to take advantage of the improvements which might be made; with a view to encourage which, and to draw the attention of Engine-makers to the subject, something in the way of a premium, or an assurance of preference, might be held out to the person whose Engine should, upon experience, be found to answer the best. The Rainhill Engines would at the same time enable you to judge of the comparative advantages of the two systems, and if upon any occasion the trade should get beyond the supply of *loco-motives*, the *horse* might form a temporary substitute.

Horse Power.

About three miles of the Brunton and Shields way are wrought by horses, the expense of which Mr. Thompson finds to be equal to $\frac{45}{100}$ of a penny per ton of goods per mile upon a level road, and my calculation makes it $\frac{43}{100}$ of a penny; but this is at the animal's best speed, or about 2½ miles per hour.

The Darlington company pay a halfpenny per ton of coal per mile, for the horse hire and driver; consequently, they pay 10d. for every ton of coal that is led to Stockton, a distance of 20 miles, but this also includes the bringing back of the empty waggons. The loco-motive Engine-men find coals, oil, tallow, hemp, oil for the waggons, and their firemen or assistants, for ¼d. per ton per mile. Now if finding and repairing the Engines be estimated at ⅛d. (which appeared to be the opinion of the company's agents), there is a saving of ⅛ of a penny per ton per mile, by the loco-motive Engines, under this head; but I apprehend that the damage to the rails upon the Darlington is greater than the expense of repairing the horse-track, and that the horse labour would be as cheap to this company. This, however (like the calculation for the Brunton way above), is taking the horse at his most advantageous speed.

At an increased speed the muscular exertion is so great that the effect of the horse is much reduced, and the expense is so much increased, that if at 2½ miles per hour the cost per ton per mile be taken at $\frac{45}{100}$ of a penny, it cannot at the speed of 6 miles, be taken at less than three times that amount, or 1⅓d, and at 10 miles per hour, at not less than 3d. per ton per mile. (See Note Z.)

Horse power for heavy goods at high speeds is therefore quite out of the question for a traffic such as you expect, while exclusive of the friction of the rope and drums, the stationary Engine costs the same price per ton of goods and waggons per mile at all practicable speeds, and the loco-motive varies from this only so far as its own weight forms a part of the *load*. If in one day the loco-motive be so loaded as to have performed a full day's work, and have travelled only 33 miles, and if on another day it has moved over 66 miles, twice the quantity of power will have been employed to overcome the Engine's own friction on the second day that was on the first. The power exerted in every instant of time to overcome the friction being proportional to the space passed over, the Engine will, at a great speed, have less of her power to apply to goods. Thus, if an 8-horse Engine at 3¼ miles per hour take 41¼ tons, it will at the rate of 8 miles take only 13½ tons; but as it will travel a greater distance at the rate of 8 miles, the expense per ton per mile is by no means proportional to the decrease of load. The expense per ton per mile being at 3¼ miles per hour equal to 3, that at 8 miles is about 4.

I have thought it proper to say thus much, to give a general idea of the laws of the two steam systems and of animal labour.

Liverpool Tunnel.

The only remaining question respects the Liverpool Tunnel, the system for working which will be the same, whatever be the plan for the other part of the line, with this difference only, that with the stationary principle throughout the line, the Engines that work the plane in the Tunnel will require an addition of power to draw the waggons for 1½ mile towards the Tunnel. If the locomotives be unfit for the Rainhill and Sutton planes, they are of course more so for this Tunnel. I apprehend there can be no difference of opinion as to the kind of power to be employed here. We recommend two 60-horse Engines, the speed 10 miles per hour, the gravity of the *descending* waggons being used to assist the *ascending*. (See Note A. 2.)

Ground required.

In conclusion, I beg to add, that when so great a trade as 50 tons of goods and waggons despatched every ten minutes is contemplated, the Company would do well to embrace any opportunity that may offer for giving them an ample space of ground, particularly at the top and bottom of the Liverpool Tunnel, where they appear at present much confined. A considerable area will be required for the waggons to prevent any delay in starting from the two extreme points, and upon this much of the desired punctuality and despatch must necessarily depend.

I am, Gentlemen,

Your most obedient Servant,

J. WALKER.

Lime-House, London,

7th March, 1829.

NOTES OF REFERENCE

TO

THE FOREGOING REPORT.

Note A. Load of Loco-motive Engine.

Horses' power for calculation of Engines, 33,000 lbs. per minute, or 150 lbs. raised 220 feet per minute, or at 2½ miles per hour; therefore 150 ÷ 4 = 37.5 lbs. = horse's power at 10 miles per hour, or 375 lbs. for 10 horses, equal to friction of 30 tons (taking friction at $\frac{1}{180}$ of weight), say then .... 30 tons.

Deduct weight of Engine, Tender and Water .... 10½ „

Leaves for goods and waggons .... 19½ tons.

Or 13 tons of goods, and 6½ tons of waggons.

Note B. Estimate of Repairs, &c. of Loco-motive Engine.

	£	s.	d.
A Tube and Chimney-breast every three years, or annually	£12	10	0
Occasional repairs to Boilers	3	0	0
New Chimney each year, and deduct old................	7	10	0
Set of Chimney-bars every two months	6	0	0
Axles and Brasses, one set annually	10	0	0
Wheels	36	0	0
Tender, Carriage and Tank..............................	2	10	0
Small Repairs	12	0	0
	89	10	0
Add one-fifth for spare Engine	17	18	0
Total............	£107	8	0

NOTE C. Coal for each Loco-motive Engine.

A 10-horse Engine will take 13 tons of goods 10 miles per hour, and will go between Liverpool and Manchester three times each day—30 x 3 = 90 miles per day, and 13 x 90 = 1170 tons of goods 1 mile per day by each Engine. 1170 tons of goods at 2½ lbs. of coal per ton per mile = 2925 lbs. of coal per day, and 2925 x 312 = 912,600 lbs. per year = 380¼ tons, or say 382 tons of coal for each loco-motive Engine per year.

NOTE D. Account of Working Expenses.

Engine-man's Wages, at 21s. per week	£54	12	0
Boy to assist	26	0	0
Coal (Note C.) 382 tons at 5s. 10d. (price given us)	111	8	4
Grease, Oil, Hemp, &c..............................	12	0	0
Total........	£204	0	4

NOTE E. Loco-motive Engines for Rainhill and Sutton inclined planes, at 10 miles per hour.

10-horse Engine upon these planes can draw 10½ tons at 10 miles per hour (by text of Report).

13 tons of goods = 19½ tons of goods and waggons.

If 10½ tons, weight of one Engine and Tender require. . 10-horse power,
Another Engine without tank or water carriage, 8½ tons, will require .... 8 horses;
And in the same proportion, 19½ tons of goods and carriages will require .... 18½ horses.
Total power........ 36½ horses.

NOTE F. Loco-motive Engines for Rainhill and Sutton, at five miles per hour.

Horse's power at 5 miles = 150 ÷ 2 = 75 lbs., or for 10 horses, 750 lbs.
Deduct gravity and friction of carriage .... 375 „
Leaves applicable to load .... 375 lbs.

375 lbs. ÷ 35.77 lbs (resistance of one ton by text) gives gross 10½ tons,
Or goods only 7⅓ tons.

Note G. Loco-motive Engine on level at eight miles per hour.

Horse power at 8 miles $= 150 \times 2\frac{1}{2} \div 8 = 47$ lbs., or for 10 horses, 470 lbs.

Then $470 \div 12\frac{1}{2}$ (resistance of one ton) gives	37.6 tons.
Deduct Engine, &c.	10.5 „
Leaves goods and waggons	27.1 tons.

Or goods 18 tons, and waggons 9 tons.

Note G 2. Time of Loco-motive Engine on inclined Planes.

$27 + 10\frac{1}{2} + 8\frac{1}{2} = 46$ tons = weight of load and two 10-horse Engines (Notes G. & E).

$35.77 \times 46 = 1645$ lbs. = total resistance to 20 horses.

$1645 \div 20 = 82$ lbs. = exertion for each horse.

82 lbs. : 150 lbs. :: $2\frac{1}{2}$ miles : $4\frac{1}{2}$ miles per hour.

Note H. Fixed Engines for Rainhill and Sutton.

52 tons or 116,480 lbs. $\div$ 96, the rise of the plane, gives for gravity	1213 lbs.
Add 116,480 lbs. $\div$ 180, for friction	647 „
Together	1860 lbs.
Friction of rope $= \frac{1}{22}$ of its weight, or of 10,560 lbs	480 „
Gravity of rope $= \frac{1}{96}$ of its weight	110 „
	2450 lbs.

2450 lbs. $\div$ 31 lbs. (power of horse at 12 miles) = 80 horses, or allowing for surplus power, say 2 Engines each 50 horses' power.

Note I. Expense of Fixed Engines upon Rainhill and Sutton.

Two 50-horse Engines for Rainhill, at £1500 each	£3000
Machinery and drum-barrels	300
Engine-house and chimney	600
Engine-man's dwelling	100
Reservoir or well for water	100
Pulleys, No. 330 for each line, or 660 for the two lines at 15s.	495
	£4595

Interest on £4595 at 5 per cent				£229	13	6
General depreciation at 1½ per cent				69	0	0
Boilers, say 3 to last 12 years, difference of value £24 per ton=£480 to be expended at the end of 12 years, equal to an annual expense of				13	4	0
Fire bars annually				5	0	0
Repairs to Engine and Machinery				35	0	0
Oil, Tallow, Hemp, &c				20	0	0
Wear and tear of Pulleys				25	0	0
Coals equal to 80 horses working 12 hours per day, allow 15 lbs. of small coal per horse per hour, which gives for 312 days 1872 tons, at 2s. 6d. (price given to us)	£234	0	0			
Add coal for raising steam, 377 tons at 2s. 6d.	47	2	6			
				281	2	6
Wages as follow:—						
Engine-man	£54	12	0			
Fireman	39	0	0			
Brakeman	39	0	0			
				132	12	0
Men to grease sheaves, one man to both planes, say for each plane				19	10	0
Oil, 150 gallons at 2s. 6d.				18	15	0
				848	17	0
Similar Engine and expense for the other plane				848	17	0
				1697	14	0
Ropes; 4 ropes for these two inclines, each 2640 yards long, 5½ inches circumference=4 lbs. to one yard, each rope therefore 94 cwt. 1 qr. 4 lbs. and the 4 ropes 18 tons 17 cwt. 16 lbs. which at £42 per ton (being £51 less £9 for old ropes), gives £792						
Interest upon £792 capital at 5 per cent.	£39	12	0			
Annual expense of ropes being for 4000 tons passed 3 miles daily for 312 days at $\frac{7}{100}$ of a penny per ton per mile upon a level, and adding for slope of 1 in 96, being nearly three times the wear upon a level	3276	0	0			
				3315	12	0
Making total				£5013	6	0

NOTE K. Expense of Water Stations.

A two-horse power Engine to each station	£200
Pumps, kettle and machinery	100
Engine-house and cistern	150
Cottage for man	60
Well or pond	50
	£560

Interest and depreciation on £560 at 6½ per cent	£42	0	0
Wear of boiler and bars, grease, &c	5	0	0
Coal for Engine, kettle, &c.—50 tons at 2s. 6d	6	5	0
Engine-man	39	0	0
	£92	5	0

10 Stations at £92. 5s. each, £922. 10s.

NOTE L. Power of Stationary Engines.

Friction of 52 tons = 116,480 lbs. ÷ 180 =	647 lbs.
Friction of ropes, sheaves and drums = $\frac{1}{22}$ of weight, say of 3,400 lbs. (being weight of 1½ mile of 3½ inch rope), equal to	155 lbs.
Friction of rope upon barrel	13 lbs.
	815 lbs.

Power of horse at 12 miles = 150 × 2½ ÷ 12 = 31 lbs. then, 815 ÷ 31 = 26 horses, or say, allowing for spare strength, 30 horses.

NOTE M. Expense of Fixed Engines at Manchester end.

Two 12-horse Engines, each £500	£1000
Machinery and drum-barrels	200
Engine-house and chimney	400
Dwelling-house	75
Well and pump, or pool for water	50
	£1725

NOTE N. Expense of Fixed Engines upon 1½ mile stages.

Two 30-horse Engines, each £1200	£2400
Machinery, drums, &c.	400
Engine-house and chimney	500
Dwelling-house	100
Well or pool for water	100
	£3500

Fifteen Engines at £3500 = £52,500.

NOTE O. Expense of Fixed Engines for middle of the 2 miles level, and at the foot of each plane.

Two 20-horse Engines, each £900	£1800
Machinery and drums	300
Engine-house and chimney	450
Dwelling-house	75
Well or pond	85
	£2710

Three Engines at £2710=£8130.

NOTE P. Expense of Fixed Engines to Work Planes.

Two 60-horse Engines, each £1800	£3600
Machinery, drums, &c.	500
Engine-house and chimney	700
Dwelling-house	100
Well and pond	100
	£5000

Two Engines at £5000=£10,000.

NOTE Q. Estimate of Repairs & Working expenses of Stationary Engines.

	£	s.	d.
Repair to boilers of Engines for the power of 1354 horses, taken in the proportion of £13. 4s. to 100 horses	£178	14	6
Fire bars taken in like proportion at £5.	67	14	0
Repairs to Engines and Machinery, at 7s. for one horse's power..	473	18	0
Oil, Tallow, Hemp, &c. at 4s. for one horse's power	270	16	0
Coal in proportion to former estimate for 100-horse Engine=18.72 tons per horse, or 25,346$\frac{88}{100}$ tons per annum, exclusive of coal for raising steam (Note S.) at 2s. 6d. .	3168	7	2

Men required as follows:—

	Manchester Engine.	Fifteen 1½ mile Engines.	Three 20-horse Engines.	Two 60-horse Engines.	Liverpool Tunnel extra.	Total.			
Engine-men..	2	30	6	4	1	= 43	at £54 12	= £2347	16
Bankmen....	2	30	6	4	2	= 44	„ 39 0	= 1716	0
Brakemen ..	1	30	6	4	1	= 42	„ 39 0	= 1638	0
Assistants ..	0	15	3	2	1	= 21	„ 39 0	= 819	0
10 men to oil pulleys, at £39								390	0

	£	s.	d.
	6910	16	0
Oil, 30 miles at 50 gallons per mile=1500 gallons at 2s. 6d.	187	10	0
	£11,257	15	8

NOTE R. Capital and Interest upon Rope.

	£	s.	d.
114 miles of 3½-inch rope at 1⅔ lb. per yard, is 104 tons, 12 cwt. 3 qrs. 14 lbs. at £51 per ton for new	£5336	16	8
Less £9 per ton for old	941	16	8
	£4395	0	0

Interest on £4395 at 5 per cent. = £219 15 0.

NOTE S. Sundry Expenses and Charges of Stationary system.

	£	s.	d.
30 crossings by iron pipes, capital £300 at 5 per cent	£15	0	0
Coal each morning for raising steam, 28 lbs. per horse per day for 1354 horses for 312 days	616	2	6
Wear of pulleys, in proportion of £25 for 3 miles........	250	0	0
Interest upon duplicates, say 1354 horses at £1 = £1354.	67	14	0
Ropes, capital as above (note R)..£5336 16 8			
For planes per loco-motive estimate 961 14 3			
6298 10 11 at 5 per ct.=	314	18	0
Interest upon signals, £550 at 5 per cent...............	27	10	0
	£1291	4	6

NOTE T. Work of Darlington Loco-motive Engines reduced to a level surface, the rise of this way *averaging* 1 *in* 246.

Hackworth's Engine.

This Engine's draught, as stated in the text, is equal to the following upon a level surface:—

	Summer.			*Winter.*		
	5 *miles.*	8 *miles.*	10 *miles.*	5 *miles.*	8 *miles.*	10 *m.*
Goods	46.75	25.00	17.75	39.90	21.00	14.30
Waggons	23.10	12.50	8.80	19.80	10.20	7.20
Engine and Tender.	16.50	16.50	16.50	16.50	16.50	16.50
Tons..	86.35	54.00	43.05	76.20	47.70	38.00

Smaller Engines.

	Summer.			*Winter.*		
	5 *miles.*	8 *miles.*	10 *miles.*	5 *miles.*	8 *miles.*	10 *m.*
Goods	34.66	18.66	13.33	28.75	15.00	10.33
Waggons..........	17.33	9.33	6.66	14.50	7.50	5.20
Engine and Tender.	12.00	12.00	12.00	12.00	12.00	12.00
Tons..	64.00	40.00	32.00	55.25	34.50	27.53

NOTE U. Experiment with Loco-motive Engine upon Bolton Railway, reported by Mr. Sinclair.

	Cwt.	Lbs.
Weight of one waggon..	30	0
Weight of its load......	42	96

72 96=8160 lbs. × 13 waggons=106,080 lbs.

Add Engine =10 tons, 13 cwt. .... 23,856 „

Mass moved .... 129,936 lbs.

129,936 lbs. ÷ 180 = 722 lbs. = friction.
129,936 lbs. ÷ 432 = 301 lbs. = gravity.

1023 lbs.

Frict. of 1 Ton.
1023 lbs. × 8.8 miles = 902.44 lbs. ÷ 12.5 lbs. =72.2 tons,
Deduct Engine....10.5 „

Gross......61.7 tons,
Deduct ⅓ for waggons......20.5 „

Goods....40.2 tons, or say 41 tons.

NOTE V. Bolton Loco-motive Engine, with 8 waggons, at 6 miles per hour.

By note U. above, one load gross = 8160 lbs. which
×8 waggons =.................................... 65,280 lbs.
Add Engine................ 23,856 lbs.
Mass moved........ 89,136 lbs.

89,136 lbs. ÷ 180 = 495 lbs. = friction.
89,136 lbs. ÷ 432 = 206 lbs. = gravity.
701 lbs. = resistance.

Frict. of 1 Ton.
701 lbs. × 6 miles ÷ 10 miles = 420 lbs. ÷ 12.5 lbs. = 33.6 tons
Deduct Engine.......... 10.6 tons
Gross.... 23 0 tons
Deduct ⅓ for waggons........ 7.6 „
Goods.... 15.3 tons, or 15⅓ tons

NOTE W. Hetton Loco-motive Engines, by Mr. Wood's Report.

In 30.00 chains falls..........14 ft. 0 in. which is equal to 1 in 141
72.45 „ .... 9 „ 3½ „ „ 1 in 514
In 102.45 chains falls..........23 ft. 3½ in. which is equal to 1 in 287

In summer takes down 16 waggons containing 848 cwt. of coal
Add waggon.......... 512 „
Engine, &c......... 210 „
Together..1570 cwt.

20 journeys = 51 miles per day, say 4¼ miles per hour for 12 hours, or, allowing for stoppages, 5 miles per hour.

1570 cwt. = 175,840 lbs. ÷ 180 = 977 lbs. = friction.
Deduct...... 175,840 „ ÷ 287 = 612 „ = gravity.
Resistance descending 365 lbs. ÷ 12½ = 29 tons, load down

512+210=722 cwt.=80,864 lbs.÷180=449 lbs.=friction.
Add 80,864 „ ÷287=282 „ =gravity.
Resistance ascending 731 lbs. ÷ 12½=58½ tons, load up
87½ tons.
Divide by 2 for average or on level..43¾ tons.

But as the rise on part of the road is not favourable, say the work on a level is 50½ tons at 5 miles per hour.

Upon this basis the work at different speeds is as follows:—

	5 miles.	*8 miles.*	*10 miles.*
Goods	23⅓	14	$9\frac{9}{10}$
Waggons	16⅔	7	$4\frac{9}{10}$
Engine........	10½	10½	10½
	50½	31½	25¼

Now 50½ tons at 5 miles = 101 tons at 2½ miles, and 101 ÷ 12 = $8\frac{5}{12}$ horses' power.

NOTE X. Friction of Rope on the Brunton and Shields Railway.

By observation, seven empty waggons took down rope in 3′ 45″ (= $8\frac{4}{10}$ miles per hour), which makes friction ...... 88¾ lbs.

Mr. Thompson says 8 waggons take it down in 3 minutes (= 10½ miles per hour), which gives friction .... 82 „

Average friction.................. 85½ lbs.

Weight of rope = 1861 lbs. ÷ 85½ = 22, or say friction of rope, sheaves, barrel, brake, &c. = $\frac{1}{22}$ of weight of rope.

Killingworth.—16 empty waggons descended Killingworth plane in 4 minutes with 4¼ inch rope after them, of which the weight was 3096 lbs. Inclination of plane 1 in 62½. This leaves for friction of rope, &c. 143½ lbs., or say $\frac{1}{22}$ of weight nearly.

NOTE Y. Rope on Brusselton Plane.

1851 yards—inclination 1 in 33½—ascended with load.
825 yards— „ 1 in 30½—descended with load.

Average taken at 1 in 33. which gives 69 lbs.=gravity of 1 ton.

$$\begin{array}{rl} & \text{Tons.} \\ \left.\begin{array}{r} 1851 \times (69 + 12\tfrac{1}{2}) \times 1.5 = 226{,}284 \\ 825 \times (69 - 12\tfrac{1}{2}) \times 1.5 = 69{,}919 \end{array}\right\} & \text{loaded.} \\ \left.\begin{array}{r} 825 \times (69 + 12\tfrac{1}{2}) \times .5 = 33{,}618 \\ 1851 \times (69 - 12\tfrac{1}{2}) \times .5 = 52{,}292 \end{array}\right\} & \text{empty.} \end{array}$$

$$382{,}113 \div 12\tfrac{1}{2} = 30.569$$

$$\begin{array}{r} 30.569 \div 1760 = 17.37 \\ \text{Deduct}\ldots\tfrac{1}{3} = 5.79 \\ \hline 11.58, \text{ say } 11\tfrac{1}{2} \end{array}$$

11½ miles: 1 mile: : .25d, : .0243 of a penny.

NOTE Z. Horse's Power.

At 2½ miles per hour, a good horse will, upon a good road, go 20 miles per day with 32 cwt. including the carriage. The effect per day is therefore 32 cwt. × 20 miles ..640 cwt. moved one mile.

At 6 miles per hour in the short stages round London, a lighter horse of nearly the same value will go 16 miles with 17½ cwt. (say coach 20 cwt., passengers 13½ cwt., and packages 1½ cwt.) equal to 17½ cwt. × 16 miles ....280 cwt. moved one mile.

At 10 miles a still lighter horse will not do more than 10 miles per day in a mail coach with 10 cwt. (say coach 20 cwt., passengers 12 cwt., bags and parcels 8 cwt. = 40 cwt.) say 40 cwt. ÷ 4 = 10 cwt. × 10 miles....100 cwt. moved one mile.

Therefore at 2½ miles per hour the horse does the work of 2¼ horses at 6 miles, and of 6½ horses at 10 miles per hour; besides at the high speed, the horse will not last half the time he will at the low speed.

NOTE A 2. Engines for Liverpool Tunnel.

1970 yards long-rise 1 in 48. lbs.
Gravity = 2240 ÷ 48 = ... 46.66
Friction = 2240 ÷ 180 = ... 12.44

Together.............. 59.10lbs = resistance of one ton

Goods and waggons............ 52 tons
Rope 7 inches = 6⅔ lbs. per yard = 5½ „

Together.............. 57½ tons, total weight to be raised
Deduct ⅓ of 52 tons = .. 17½ tons, descending empty waggons

Leaves...... 40 tons preponderance

40 tons × 59.10 lbs. resistance .... 2364 lbs.
17.5 + 17.5 = 35 tons, ascending and descending waggons.. 35 × 12.44 =................... 435.4 „

2799.4 lbs.
Gravity of rope = 5.5. tons × 46.66 = ... 256.6 „
Friction of rope = $\frac{1}{22}$ of 5½ tons = ... 597.0 „

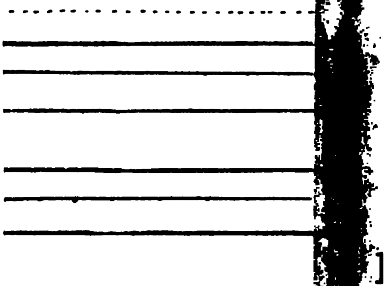
3653 lbs.

3653 ÷ 37½ (horses' power at 10 miles) = 97½ horses = power of Engine, say 100 horses, or two of........................ 50 horses.
Add for stage, 1½ mile, goods drawn towards Liverpool, say
two of .... 10 „
Two of............ 60 horses.

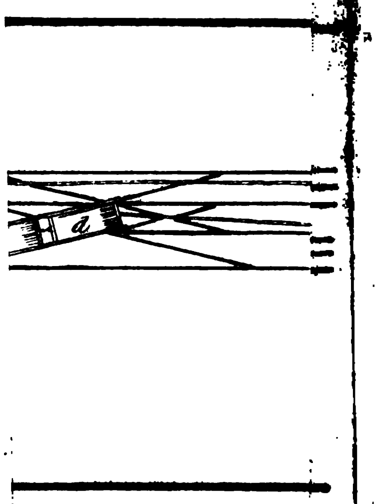
C. Baynes, Printer,
Duke Street, Lincoln's Inn Fields.

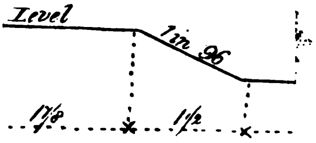
IOTHECA·BODLE

Mr



e track of one train go





Section

OBSERVATIONS
ON THE
COMPARATIVE MERITS
OF
# LOCOMOTIVE & FIXED ENGINES,
AS APPLIED TO RAILWAYS;
BEING A
Reply to the Report of Mr. James Walker,
TO THE DIRECTORS OF THE LIVERPOOL AND MANCHESTER RAILWAY,
COMPILED FROM THE REPORTS OF MR. GEORGE STEPHENSON.

WITH
AN ACCOUNT OF THE COMPETITION
OF
LOCOMOTIVE ENGINES AT RAINHILL,
IN OCTOBER, 1829,
AND OF THE SUBSEQUENT EXPERIMENTS.

BY
ROBERT STEPHENSON AND JOSEPH LOCKE,
CIVIL ENGINEERS.

LIVERPOOL:
PRINTED BY WALES AND BAINES;
AND SOLD BY THEM AND THE BOOKSELLERS IN LIVERPOOL; HURST, CHANCE AND CO. LONDON;
CADELL AND CO. EDINBURGH; J. BAINES AND CO. LEEDS; BANCKS AND CO.
MANCHESTER; AND CHAS. EMPSON, NEWCASTLE-UPON-TYNE.

THE increasing importance of Railway communications renders it very desirable that the principle of applying Steam power should, in all cases, be well understood; and from the interest which has been excited by the late discussions on the best method of conveying goods on the Liverpool and Manchester Railway, it is evident that the public, as well as the Proprietors of that great work, are not insensible of the advantages to be derived from its application.

It was in the latter part of 1828 that the Directors of the Liverpool and Manchester Railway turned their attention to this subject. The great expense which has been incurred in forming the works rendered this an investigation of much importance.

A Deputation from that body made a tour through the northern part of the country for the purpose of collecting information from the experience of others: their opinion was decidedly adverse to Horse Power, and rather in favour of Fixed Engines.

Mr. Stephenson, the Company's Engineer, next visited Darlington and Newcastle, and inspected those Railways, where both kinds of power were employed. In this investigation we accompanied him, wherein we had every opportunity of ascertaining the actual cost of conveyance and the liabilities of derangement to which each mode was subject. Mr. Stephenson, in his Report to the Directors, expressed himself decidedly in favour of Locomotive Engines.

This Report differing in some degree from that of the Deputation, it was deemed necessary, in order to come to a satisfactory conclusion, to employ two Engineers, who might be able to give the subject their full consideration.

Mr. James Walker, of London, and Mr. Rastrick, of Stourbridge, were named, and appointed to inspect the Railways in the north: they devoted a considerable portion of time to the examination, and embraced a very comprehensive view of the subject.

These gentlemen, however, did not seem to be very urable to one system more than another, although considered Fixed Engines to be the most mical; and they differed essentially in several very important items of expenditure with which Mr. Stephenson had previously made himself acquainted.

Notwithstanding the conclusions to which Messrs. Walker and Rastrick had arrived, the majority of the Directors still believed that Locomotive Engines, from the simplicity of their application to any quantity of trade, would best answer the purposes of their Railway. Under this impression they offered a premium of £500. for the best Locomotive Engine which, being constructed on the principle of burning its own smoke, should take a certain weight at a given speed. This offer induced the competition which took place at Rainhill in October last, an account of which will be found in the following pages.

The Reports of Messrs. Walker and Rastrick were printed by the Directors and circulated amongst the Proprietors, since which Mr. Walker has revised and republished that part which was written by himself, and caused it to be generally circulated. It is our object to examine how far the statements it contains are consistent with the experience before us.

We indulge not in speculative theories, and we shall offer no opinion that has not been substantiated, either by daily practice or more recent experiments.

Liverpool, February, 1830.

OBSERVATIONS, &c.

The advantages which Railways possess over every other mode of conveyance at present known, are not only attributable to the smooth and hard surface which the iron rails present to the wheels of carriages rolling upon them, but also in a great degree to the facility of applying Steam power as a Locomotive Agent.

It is considered by some that horses, in point of economy, are preferable to Locomotive Engines; while others have advocated that mode called "the reciprocating plan of conveyance by Fixed Engines." Each system has its peculiar advantages, depending chiefly on the nature of the surface of the country, and on the extent and character of the trade.

The horse may be said to be preferable when the quantity of goods to be conveyed is small, the distance short, and when coals are so scarce as to render the use of steam power less economical.

Locomotive Engines are best adapted for Railways that are continuous and horizontal, where the desideratum is despatch, and particularly when the conveyance of passengers becomes an important part of the trade.

Fixed Engines with ropes are most suitable for hilly countries, where the gravity of the horse, as well as of the Locomotive Engine, becomes a material part of their whole power.

It may easily be imagined that a difference of opinion may exist, as regards the economy of these different modes, in their application to particular localities. Our object is to compare the merits of Locomotive and Fixed Engines on a horizontal Railway (or nearly so).

Previous, however, to entering into the question of the general conclusions to which Mr. Walker has arrived, we shall examine the correctness of the data employed by him in the following order:—

1st. Friction of Railway Carriages.
2d. Estimate of the mechanical effect of a Locomotive Engine moving at the rate of 10 miles per hour, and its requisite weight.
3d. The mode adopted for ascertaining the average performance of Locomotive Engines at present in use on the Darlington and other Railways.
4th. The consumption of fuel.
5th. Annual repairs.

The friction of carriages moving on Railways is certainly not " well agreed," as Mr. Walker has supposed, to be $\frac{1}{180}$th of the weight moved, or 12½ lbs. per ton. The most popular work on this subject, and where the most care seems to have been taken to procure accurate results, is that of Mr. Wood, who instituted a set of experiments for the purpose: he has invariably represented friction at $\frac{1}{200}$th, or $11\frac{1}{5}$ lbs. per ton; and, considering the imperfect state of the road where these experiments were made, we should not think that it would be increased on a "well-constructed Railway." Indeed, from some experiments recently made on the Liverpool and Manchester Railway, with a carriage having the bearings on the outside of the wheels, the friction was found to be only $\frac{1}{280}$th of the weight, or 8 lbs. per ton; but, since these experiments were made under the most favourable circumstances (the rails being previously swept), with a new carriage fitted up for the purpose, whilst those of Mr. Wood were made under all states of the road, and with waggons that had been for some time in use, we have thought it better to adopt his formula: and we know of no experiments that could warrant friction to be represented at $12\frac{1}{2}$ lbs. per ton, except those which Mr. Walker himself made on a stone pavement road which is now constructing in the neighbourhood of London, and which, we believe, was exactly $12\frac{1}{2}$ lbs. per ton; but no one for a moment can suppose, that the resistance on a smooth iron Railway can be as much as on a stone road. Smoothness and hardness are necessary qualities in a good road, and so long as iron possesses them in a greater degree than stone, it follows that the amount of friction will ever be less.

In estimating the effect of a Locomotive Engine moving at the rate of 10 miles per hour, Mr. Walker commences by assuming the power of an engine weighing 8 tons to be uniformly equal to 10 horses, and a horse equal to 33,000 lbs. raised 1 foot per minute.

Much has been said by various writers on mechanics respecting the uncertainty attending the practice of designating the power of machines in terms of horses, since eminent Engineers differ widely in their estimate of the latter power. This difference of opinion, however, is of little importance so long as it is understood upon which formula we found our calculations. We shall, therefore, for the sake of clearness adopt the same estimate of a horse's power as Mr. Walker has done, viz. 150lbs. moving at the rate of 2½ miles per hour.

The effect of high-pressure Engines is now almost universally admitted to depend, not so much on the size of the cylinder, as upon the quantity of steam which the boiler can generate, and upon its degree of elasticity. The capability, therefore, of a high-pressure Engine is most accurately ascertained by the size and construction of the boiler, and more especially by the latter, since the quantity of steam supplied by boilers of the same dimensions is materially influenced by the manner in which the fire is applied. To explain this by an example, let us suppose two high-pressure Engines constructed precisely alike in every particular, except in the height of the chimney: in this respect let one have a chimney 20 feet high, and the other one of 40 feet high; it is clear that the draft created, and consequently the temperature of the fire connected with the latter, will be much greater than that connected with the former.

Supposing, under these circumstances, that the quantity of steam generated, and the consumption of fuel, be in direct proportion to the temperature, it is obvious that the power of the two Engines will be proportionate to the quantity of fuel consumed.

Hence we perceive that the power of high-pressure Engines is more directly connected with the quantity of fuel consumed in a given time than with the size of the cylinder, or even the capacity of the boiler itself. We are aware that the above assumption relative to the quantity of steam and consumption of fuel being in the direct ratio to the temperature of the furnace, may be deemed gratuitous. This does not, however, affect the result, for it is clear that the quantity of steam generated in a given time, and also the quantity of fuel consumed, will bear some proportion to the temperature. Whatever this proportion may be, the respective powers of the Engine will still be governed by the quantities of fuel more than by the size of the boiler, or any other part of the Engine. It will, therefore, be readily inferred that as much steam may be generated in a small boiler as in a large one, if the temperature of each be duly proportioned; or in other words, the same Engine may be greatly increased in power by applying means to increase the temperature of the fuel.

In taking this view of the subject of Steam Boilers, no regard is paid to the comparative economy of fuel, it not being our object in this place to enter upon a subject on which there are two opinions so widely different. Some Engineers maintain that economy in the consumption of fuel applied to Steam Engines is most efficiently accomplished by allowing combustion to proceed at as low a temperature as is consistent with circumstances, and make up for a deficiency in this respect by increasing the quantity of fuel in combustion, and also the surface by which the caloric is transmitted to the water in the boiler. The truth of this view of the subject is not unfrequently very strikingly exemplified in practice. The other opinion, which is advocated by several scientific gentlemen, is diametrically opposite to that already mentioned. It is maintained that the more elevated the temperature the greater is the economy of fuel. This opinion hence differs from the former by substituting intensity of temperature for area of heating surface.

In Locomotive Engines hitherto constructed, the area of the surface in the boiler acted upon by the fire is much less than that generally employed in Stationary Engines, and hence it is that the consumption has been much greater to produce equal effects. This inconvenience has been submitted to, in order that simplicity and compactness might be achieved.

To compensate for the loss of heating surface it was necessary to augment the temperature of the fire. This was effected, shortly after the first Locomotive Engine was tried on the Killingworth Colliery Railway, by conveying the steam into the chimney, where it escaped in a perpendicular direction up the centre, after it had performed its office in the cylinders. The velocity of the steam on entering the chimney being much greater than that due to the ascending current of air from the natural draft of the furnace, the effect was to increase the draft and consequently the temperature of the fire.

From what has already been said respecting the connection existing between the power of high-pressure Engines, the temperature of the furnace, and consumption of fuel, it is obvious by this contrivance for augmenting the draft, that a corresponding increase takes place in the power of the Engine. This being admitted, to which there is no reasonable objection, let us suppose that a Locomotive Engine, moving at the rate of 4 miles an hour, has its velocity increased (by reducing the load one half) to 8 miles per hour—it is evident the steam from the cylinders will escape into the chimney at twice the velocity; an increase of draft is the result, accompanied with a more rapid consumption of fuel, and consequently a more profuse generation of steam. Since it has been shown that the power of these Engines, under similar circumstances, is chiefly dependent on the quantity of fuel consumed, it is evident that by this application of the waste steam to accelerate combustion, the power of the Engine actually varies under different velocities. The precise law by which this augmentation of power is governed remains yet to be determined, and must depend on future experiments. The detail of experiments made with the "Rocket," at Rainhill, subsequent to the competition, will suffice to prove, without doubt, that such an increase of power does really take place as the velocity of the Engine is multiplied. This curious fact, connected with the construction of Locomotive Engines on the principle of the "Rocket," has not hitherto, we believe, been represented in this manner; and it is so important, that any calculation neglecting its consideration at high velocities must be regarded as futile and absolutely false.

Mr. Walker takes the power of a Locomotive Engine, of the size and construction of those used upon the Darlington Railway, equal to 10 horses, at 2½ miles per hour. Presuming that the effect is inversely as the velocities, he reduces the power of the Engine at 10 miles per hour to 2½ horses power, or = 375 lbs. This conclusion would have been perfectly correct if the quantity of steam generated in the boiler in equal times were the same at all velocities; but the fallacy of this assumption, in reference to Locomotive Engines, has been sufficiently explained in the foregoing remarks.

From the method adopted by Mr. Walker to ascertain the effect of Locomotive Engines at different velocities, he deduces a gross weight of 19½ tons at 10 miles per hour, as a proper load for an Engine weighing 8 tons. The weight of a Locomotive Engine is so very important in the inquiry, that we are surprised that no reason has been assigned for stating it at 8 tons. It ought not to be inferred, that because the Engines on the Darlington Railway are of this weight, that similar ones would be required on the Liverpool and Manchester Railway, where the occasional ascents to be overcome are trifling, when compared with those on the former.

To explain this more clearly: on the Darlington Railway, although its average fall be 1 in 246, there are several planes which are level, or nearly so, and others that ascend 1 in 100. The Engines have to overcome in their regular work the resistance of 20 loaded waggons on a level, and of 20 empty ones on an ascent of 1 in 100, at the rate of 4 miles per hour.

Weight of 20 loaded waggons = 80 tons
Engine and Tender .... = 12 „
92 tons,

or 206,080 lbs. ÷ 200 = 1030 lbs. the maximum resistance with a load at 4 miles per hour, $\frac{1030 \times 4}{10} = 412$ lbs, at 10 miles per hour:—

In returning, weight of Carriages 25 tons
Engine and Tender...12 „
37 = 82,880 lbs,

82,880 ÷ 200 = 414 lbs. friction.
82,880 ÷ 100 = 828 „ gravity.
1242 „ the maximum resistance with the empty waggons, at 4 miles per hour, or $\frac{1242 \times 4}{10} = 497$ lbs. at 10 miles per hour.

But since Mr. Walker takes 375 lbs. as the effect of a 10 horse Engine, it follows that the Darlington Engines are daily working to upwards of 13 horses' power, yet they do not exceed 8½ tons, exclusive of tender. If we examine the statement sent by Mr. Sinclair to Mr. Walker, respecting the performance of the "Lancashire Witch," on the Bolton and Leigh Railway, where 8 waggons, each weighing 8160 lbs., form the fair every-day load, and are propelled up an ascent of 1 in 432 at the rate of 6 miles per hour, then—

8160 lbs. × 8 + 23,856 lbs. (weight of Engine & Tender) = 89,136 lbs. total weight moved.

$\frac{89,136}{432} = 206$ gravity.

$\frac{89,136}{200} = 445$ friction.

651 lbs. total resistance.

And $\frac{651 \times 6}{10} = 390.6$ lbs. which, at 11⅕ lbs. for friction, leaves, after deducting weight of Engine and waggons, 16 tons of goods at 10 miles per hour; but allowing it to be only 15⅓ tons, which Mr. Walker admits to be the "practical, fair, every-day's work" of this Engine, it is easily shown, that the difference between 15⅓ tons and 13 tons for an Engine's load affects very materially the ultimate results. It is calculated that 2,000 tons will pass each way between Liverpool and Manchester daily, which is equal to 4000 tons over 30 miles, or 120,000 over 1 mile. One Engine is proposed to travel 90 miles per day with 13 tons of goods, equal to 1170 tons over 1 mile; consequently, 102 Engines would be required to perform the work: but if each Engine took 15⅓ tons, only 87 Engines would be required. Therefore 15 working and 3 spare Engines would be saved, which would produce a reduction in the first cost amounting to near £11,000. and a saving in annual cost of nearly £5000.

This calculation is brought forward to show how important it is to take into account the most recent improvements in this class of Engines. The "Lancashire Witch" was the most efficient Mr. Walker had examined, and the deductions from its performance would have approximated nearer the truth, than data drawn from the Darlington Engines that have been several years in use, and working under very great disadvantages.

Scarcely a single journey is performed by these Engines without being interrupted by the horses or other trains of carriages passing in a contrary direction, there being only a single line of road, with passing places. At each end of the distance traversed by the Engines great delay is occasioned from the irregular supply of carriages, which, from the nature of the trade, and other local circumstances, it is impossible to avoid.

None of these disadvantages are taken into consideration by Mr. Walker; he even neglects the consideration that all the Engines he examined were constructed to move at moderate velocities, and in determining the effect produced by those used at Darlington, a most unaccountable oversight is committed. In this distance several different rates of ascent occur, where the Engine is required to exert a power much beyond the average performance. In the adaptation of Engines to this line, it was requisite to construct them in such a manner that these ascents might be surmounted without difficulty, though such a construction would render them less suitable to the more favourable parts of the line of road. This is evidently a great drawback, for which, instead of making a due allowance, the line is assumed by Mr. Walker to ascend uniformly at the rate of 1 in 246, being the average of a series of planes, varying from a level to an ascent of 1 in 100. Several miles of the distance ascends from ¼ to nearly ⅜ of an inch per yard, where the Engines are daily exerting a much greater force than Mr. Walker affixes to them; and it ought to be observed that this increase of power is not called into action by any improper means, such as he supposes to take place when experiments are made merely to show what the Engine will do. It is remarkable that this method should have been adopted in calculating the actual performance of the Engines, when in another part of his Report Mr. Walker says—

" From the account of work of the Hetton Engines, " we find they are doing less than the others, owing, " as we have calculated, to the rise in one part of " their journey being too great for their application."

Now, if the rise in one part of the line of road in this instance reduces the effect of the Engines, is it not evident that the ascents in the Darlington Railway should operate in the same manner, and in a proportionate degree? Though this is, from the above extract, Mr. Walker's opinion, he has deserted it entirely in making his calculations respecting the performance of the Darlington Engines. In order to show, in as clear a manner as possible, the inconsistency of estimating the effect of a Locomotive Engine on a level, from that produced on a road consisting of a series of inclined planes, some of which nearly approach the utmost limits of ascent where Locomotive Engines can be profitably employed, we will take an imaginary case, where animal power is used. Let us suppose that a Railway, 20 miles long, ascends on an average 10 feet per mile, making the total ascent 200 feet. If the ascent in the first instance be taken uniformly, a horse will pass over 20 miles with a load of 7 tons, which may be considered a fair average day's work. Instead of the ascent being uniform, let it be irregular, and in some places to ascend so rapidly as to require an assistant horse, to enable the load to pass uninterruptedly. Here, therefore, we are compelled to have two horses to accomplish the same work that one would do if the ascent were uniform. It must be granted that the assistant horse would not in this case be fully employed; but although the additional power may not be fully employed, it is still necessary to overcome the increased resistance.

This case is a precise parallel to the Locomotive Engines on the Darlington Railway.

In quick ascents they exert occasionally, in ascending with the empty waggons, a force equal to 1242 lbs., whereas if the road be assumed to ascend uniformly 1 in 246, the greatest resistance would only be 751 lbs. We may take an extreme case, by conceiving a Railway to consist of a number of level planes, with intermediate ascents so great as to require the whole power of the Engine to propel itself. Here Locomotive Engines would be entirely useless; whereas if the ascent were made uniform, they might be the best possible kind of motive power that could be employed.

The consumption of fuel being much greater in Locomotive than Fixed Engines, it becomes a highly interesting, and indeed an essential point to determine the proportion with precision, before a correct comparison can be instituted between the merits of the two systems of conveyance.

It is probable that the consumption of fuel by Locomotive Engines will always be greater than by Fixed Engines.

In the latter the heat may, without inconvenience, be applied in the best possible manner, and care taken to prevent loss of heat by radiation; but lightness, compactness, and simplicity being absolutely necessary in Locomotives, we are compelled to adopt less economical methods of applying the fuel.

The great disparity which exists in this respect between these two kinds of Engines is a sufficient reason for making diligent inquiry on the subject.

In his estimate for coals for the Stationary Engines, Mr. Walker takes 15 lbs. per hour per horse, which is considerably below the average consumption of these Engines, except kept in the most complete order; and even with this rare condition, and great uniformity of the work to be performed, few Engines are brought so low as 17 lbs.: more generally the consumption is 20 lbs. per hour per horse power. The fuel consumed by the Darlington Locomotive Engines appears to have guided Mr. Walker in fixing $2\frac{1}{2}$ lbs. per ton per mile as the probable average consumption on the Liverpool and Manchester Railway. The information he received from Mr. Storey, the resident Engineer on the Darlington line, respecting the quantity of coals consumed in two months by 4 Engines, and of the work done in that time, is unquestionably correct; and if the Engines had been as adequately employed during this period as Stationary Engines are, when the quantity of fuel is estimated, no objection whatever could have been urged against the conclusion to which Mr. Walker had arrived; but these Engines are seldom or never kept in regular work, on account of the irregularity in the supply of waggons at each end of the journey, which has been already alluded to.

In considering the subject of fuel in reference to these Engines, it is very material to take into account the stoppages to which they are subjected, not from any inherent defect in the system or construction, but from casualties connected solely with the character of the trade.

If, therefore, certain contingencies (in those instances where Locomotive Engines are employed) occasion a wasteful expenditure of fuel, the same influence ought certainly to be calculated upon if any other species of power be applied. Mr. Walker does not, however, appear to have made any inquiry as to the consumption of fuel by Stationary Engines, where they are employed on Railways and subjected to delays similar to those we speak of on the Darlington line; and instead of drawing a just parallel on this point between the two systems, he takes the fuel consumed by Fixed Engines at a minimum, even under favourable circumstances, and employs in his estimate the maximum, or nearly so, of coals consumed by Locomotives under very unfavourable circumstances.

It is extremely difficult, if not altogether impracticable to determine accurately the quantity of fuel consumed by Locomotive Engines during the time they are actually in operation on any of the Railways where they are adopted. To arrive, therefore, at data to enable us to compare them with Stationary Engines, we are compelled to rely upon experiments made expressly for the purpose, which, if made carefully and impartially, are certainly more valuable than information derived from, and applicable only to, particular localities. When it is stated that experiment is most valuable, it must be understood that we refer to the comparison between the two classes of Engines similarly situated. Several experiments with different Locomotive Engines are detailed by Mr. Wood, in his treatise on Railways, which give the consumption of fuel as follows:—

No. 1	Experiment...2.9 lbs.	of Coal	per ton per mile.
„ 2	Ditto 2.13	ditto	ditto.
„ 3	Ditto 2.05	ditto	ditto.
„ 4	Ditto 2.34	ditto	ditto.
„ 5	Ditto 1.60	ditto	ditto.

Nos. 1 and 4 are the only experiments which could warrant the consumption taken by Mr. Walker; and when the construction of the Engine is taken into account, this large quantity of fuel required is satisfactorily explained. The experiments 2, 3, and 5, were made with wheels of 4 feet diameter, to show the economy arising from large wheels, and the result approximates much nearer a true average, as compared with Fixed Engines, than that taken from the accounts furnished from Darlington.

The above experiments were made with Engines having a single fire tube through the boiler, similar to the whole of those on the other Railways visited by Mr. Walker, excepting one at Darlington, which has a double tube, and presents a greater surface to the fire.

Mr. Walker speaks of this construction as a great improvement, yet he rejects the experiments made with this Engine (for the express purpose of ascertaining the consumption of fuel), and calculates upon the data he received from Mr. Storey, relative to the fuel required during two months by Engines which he acknowledges to be constructed upon less economical principles. That the experiment just alluded to is good data upon which to form a judgment, the following by Mr. Wood will show in a very satisfactory manner:—

The Darlington Engine with a double tube, gave the consumption................1.60 ⅌ ton ⅌ mile.
Mr. Wood's experiment, No. 2, gave 2.13 ditto.
Ditto, 3, „ 2.05 ditto.
Ditto, 5, „ 1.60 ditto.

Taking into consideration the smaller quantity of surface exposed to the fire in the Killingworth Engines, the accordance is as near as could be expected, since difference in the condition of the

Railway, as well as in the state of the weather, would occasion some discrepancy.

The "Lancashire Witch," from the Bolton and Leigh Railway, has recently been employed on the Liverpool and Manchester line, to draw marle, &c. from an excavation on a part of the road exactly level. The construction of this Engine is different from any at that time in use, and it was interesting to know whether any economy in the consumption of fuel was produced. Two distinct tubes pass longitudinally through the boiler, each of which contains a fire. The object of this arrangement was to apply a larger quantity of fire, as well as to obtain a greater extent of surface. The following experiment was made with this Engine, and the greatest attention was paid to obtain accurate results.

In 12 hours 158 waggons of marle and sand, each weighing 4 tons, exclusive of carriage, were conveyed over a distance of $1\frac{4}{10}$ miles, or 884 tons over 1 mile, without any allowance for back carriage, which was 158 waggons, each weighing 20 cwt. over $1\frac{4}{10}$ miles, or 221 tons over 1 mile. Two-thirds of the weight of the empty carriages may be supposed goods: the performance will therefore stand thus:—

884 tons of goods over 1 mile in one direction.
147 „ of ditto over 1 mile in the other direction.
1031 „ total conveyed by the Engine over 1 mile.

Coals.—15 cwt. consumed by the Engine.
1 „ in heating water.
16 „ total weight consumed.

This, divided by 1031 tons, gives 1.73lbs. per ton of goods per mile.

From the duration of this trial it almost loses the character of an experiment, and may be regarded as the nearest approximation to a fair average consumption. This is on the supposition that the Engines are fully employed, which becomes a vital condition when Locomotives are to be compared with Stationary Engines.

On the annual repairs of Locomotive Engines we agree with Mr. Walker, that there is little ground for speculation respecting the original cost of these Engines, and the men's wages in working them. So far, therefore, in our calculation, we adopt the same amounts; but we think his estimate of annual repairs is considerably overrated, and, we believe, not borne out in any single instance by experience. It would have been more satisfactory if Mr. Walker had given his reasons for estimating the annual repairs so high as to make the yearly cost of keeping, in complete order, one Locomotive amount to £107. 8s. With the exception of one item in this estimate, viz. "fire-bars," they are all at variance with our experience for upwards of 14 years; but as no explanation of the individual items is given, we refrain from entering into an investigation of each separately.

We have been favoured with an account of the actual annual cost incurred in keeping in repair the Locomotive Engines on the Springwell and Darlington Railways. On the former, two Engines have been employed about 4½ years, and, according to the account furnished by Mr. John Wood, the colliery viewer, these Engines cost, during the year 1827, as follows:—

Wright work	£10	15	5
Smith work	40	17	3
Sundry tradesmen's accounts	50	2	0
	£101	14	8
Deduct old materials	9	19	3½
Total cost of repairs for two Engines	91	15	4½
Or, for one Engine	£45	17	8¼

The same Engines cost during the year 1828:—

Smith work	£22	15	0
Malleable Iron Bars	27	8	3
Wright work	4	3	2
Sundry tradesmen's accounts, including Carting, Stop Cocks, Pumps, Clacks, &c.	31	17	6½
Total cost of repairs for two Engines	£86	3	11½
Or, for one Engine	£43	1	11¾

In 1829 the annual repairs of four of the Darlington Engines, as per account, carefully taken by Mr. Hackworth, exclusive of Fire Bars, are	£154	8	0
Add for Fire Bars	24	0	0
	£178	8	0
Or, for one Engine	£44	12	0

The near coincidence existing between these two estimates, made by different individuals, is a strong proof of their accuracy; and when we consider that they refer to Engines without springs, and some other recent improvements, we are satisfied that £50. is an ample allowance for the annual repairs of Locomotive Engines more recently made.

The necessity of employing Fixed Engines for the purpose of assisting the Locomotives to ascend the Rainhill and Sutton inclined planes, comes next to be considered.

These planes have a rise of 1 in 96, and were originally laid out for Fixed Engines; but, since that time, Mr. Stephenson has recommended the use of Locomotives entirely, and in his Report to the Directors on that subject says—

" I propose each Locomotive to take 30 tons of " goods, and to keep an assistant engine at the bottom " of each plane, which will make the load of each 15 " tons, or, with the waggons, 22 tons, and they will be " enabled to ascend at the rate of 6 miles per hour."

Mr. Walker has taken great pains to investigate this subject, and has made several calculations to shew how hopeless it is to expect Locomotives to work on these planes. He states that the effect which an Engine weighing, with its tender, 10½ tons is capable of exerting, is only 375 lbs.; and that it will only "just " move its own weight up the hill at 10 miles per hour, " and consequently, an additional number of Engines " could do no good, as the weight of each would be " its load." Adding—" It would consequently be " doing an injury to the Locomotive system to apply " it to this work, for which it is evidently unfit. " However good it may be in itself, it has its limits, " and an ascent of 1 in 96 is palpably beyond them, " where the length and requisite speed are so great."

It very fortunately happens that there is already experience enough to decide which of these two opinions approximates nearer the truth, and we are surprised that Mr. Walker should have entered into a lengthened calculation to prove what every day's experience demonstrates to the contrary; for there is no doubt but that three-fourths of the Locomotive Engines, now in use, are daily exerting a force greater than would be required to ascend the Rainhill planes at 10 miles per hour.

We have before had occasion to observe, that the Darlington Engines have frequently to exert a force equal to 1242 lbs. at 4 miles an hour, or 1242 × 4 ÷ 10 = 497 lbs. at 10 miles an hour.

On the Springwell Railway, where two Locomotives are used, and where the angle of inclination varies from $\frac{1}{810}$ to $\frac{1}{80}$, the average being 1 in 122, one Engine travels with 18 waggons weighing 22½ tons, or with Engine, &c. 33 tons, at an average speed of 6 miles per hour.

In the first place, the average resistance for the whole length of the line will be—

Gravity 606 lbs.
Friction 370 „

976 × 6 ÷ 10 = 585½ lbs. the effect at 10 miles an hour.

In the second place, the occasional resistance on a rise of 1 in 80 will be—

Gravity 924 lbs.
Friction 370 „

1294 × 6 ÷ 10 = 776 lbs.

But as this part of the road is not very long, we have thought proper to take the average of the whole line.

From an experiment made on the Bolton and Leigh Railway with the "Lancashire Witch," it appears that 58 tons were moved up an inclination of 1 in 432 at the rate of 8$\frac{8}{10}$th miles per hour, which gives the effect at 10 miles per hour equal to 836 lbs.

Mr. Walker rejects this experiment, because he supposes the safety valve was tied down, and because the distance run was not sufficiently continuous; yet we should think, that with such a load, and at a speed of near 9 miles an hour, the rapid abstraction of steam from the boiler would prevent all necessity of fastening down the valve; and the distance was very little short of the length of the Rainhill inclined plane, and therefore bears some resemblance to the point in question.

On the Hetton Railway the rise in one part is considerably more than the average of the whole length, the former requiring the Engine to exert a force equal to 488 lbs. at 10 miles an hour, while the latter, which is stated to be the Engine's real performance, is only 343 lbs.

If we recapitulate the foregoing, we shall have for the effect produced on the

Darlington Railway	497 lbs.
Springwell Railway	$585\frac{1}{2}$,,
Bolton and Leigh Railway	836 ,,
Hetton Railway	488 ,,

Now the whole of these results (excepting that of the "Lancashire Witch," just referred to) are derived from the every-day work of Engines which have been in use for the last five or six years:—and, suppose that the force requisite to propel an Engine up the Rainhill inclined plane be 375 lbs. as has been stated by Mr. Walker, it is evident that the whole of these Engines are exerting a greater force than would be required to surmount such an inclination.

The abrupt ascents which frequently occur on these Railways will, in some degree, account for the weight of the Engines employed on them. The estimate of their actual performance has been erroneously made by considering the line to rise uniformly from one end to the other, forgetting that the Engines are obliged to be made so heavy as to be able to overcome the greatest acclivity, and that the surplus weight upon other parts of the road becomes a clog upon the Engine, and reduces its beneficial effect.

But to reduce the effect of Locomotive Engines on inclined planes to a still greater certainty, some experiments have been instituted on the very plane in question, which must remove every doubt on the subject.

EXPERIMENT FIRST.——The "Rocket" Engine, weighing 4¼ tons, including the weight of water in the boiler, took a load of

Engine..................	4 tons.	5 cwt.
Tender.............. ...	2 „	10 „
Waggons and Load	8 „	10 „
	15 „	5 „

up an inclination

of 1 in 96 in 5′ 35″, the distance being 1½ mile, which is at the rate of 16 miles an hour.

EXPERIMENT SECOND.—Engine... 4 tons 5 cwt.
Tender... 3 „ 0 „
Waggons 13 „ 7 „
20 „ 12 „ up
the same inclination and the same length in 7′ 10″, which is at the rate of 12½ miles an hour.

In confirmation of these it may be added, that during several trips up this plane with a coach containing 30 persons, a speed of 24 miles an hour was maintained.

No care in these experiments was taken to render them more striking than the ordinary work of Engines would justify. The "Rocket" had a lock-up safety valve, loaded to 50 lbs. on the square inch, and the rails, if any thing, were in a worse state than they usually are. Our object being solely to ascertain whether such an inclination might not be overcome by an Engine of that weight.

That these experiments have sufficiently answered the purpose for which they were intended is quite evident; and even if facts had been wanting to prove the fallacy of Mr. Walker's position, these, from their direct application to the point in question, cannot fail to remove a difficulty which such a statement was calculated to create.

On the 19th of October some further experiments with the same Engine were made, to determine what load was best adapted for regular work. The plane was level. The distance in one direction was 1½ mile, the weight attached was 30 tons, Tender 3 tons, Engine 4¼ tons.

	Weight.	*Space.*	*Time.*
1st Trip Eastward....	37¼ tons.	1½ mile.	6′ 10″
Ditto Westward...	37¼ ,,	1½ ,,	6′ 46″
2d Trip Eastward....	37¼ ,,	1½ ,,	7′ 54″
Ditto Westward...	37¼ ,,	1½ ,,	6′ 41″
3d Trip Eastward....	37¼ ,,	1½ ,,	6′ 35″
Ditto Westward...	37¼ ,,	1½ ,,	7′ 12″

9 miles in 41′ 18″ = 13 miles ⅌ hour.

	Weight.	*Space.*	*Time.*
4th Trip Eastward....	41¾ tons.	1½ mile.	6′ 30″
Ditto Westward...	41¾ ,,	1½ ,,	6′ 45″

3 miles in 13′ 15″ = 13½ miles ⅌ hour.

	Weight.	*Space.*	*Time.*
5th Trip Eastward...	46¼ tons.	1½ mile.	6′ 18″
Ditto Westward...	46¼ ,,	1½ ,,	6′ 50″

3 miles in 13′ 8″ = 13¾ miles ⅌ hour.

It may appear singular that the increase of weight should be attended with an increase of velocity, but this may be accounted for by the steam rising during the times that the waggons were fixing on, and also by the Engine getting in better working order after a few trips; but taking every thing into consideration, we regard the average rate of performance on that day to be 37¼ tons (gross), or 20 tons of goods, at 13 miles an hour.

In an experiment which was afterwards made with a gross load of 34½ tons, in starting from one end of the stage the steam was so low that the Engine could only just move the load. During the first quarter of a mile the average rate was not more than 5 or 6 miles an hour; in the next quarter it increased, and on arriving at the other end of the stage we were moving at the rate of upwards of 12 miles an hour. No additional fuel was put into the fire during the whole length of the stage, nor was any extra steam thrown into the cylinders; in short, not a valve nor any part of the Engine was interfered with, but was left to exert such power only as an ordinary fire might be capable of generating.

Experiments generally are deemed objectionable, because the Engine is forced beyond what it is capable of maintaining; but, in this instance, there was more steam in the boiler, on arriving at the end of the stage, than there was at the commencement; and hence the conclusion, that the power of the Engine is at least adequate to move a gross weight of $34\frac{1}{2}$ tons, at the rate of 12 miles an hour: and whether the speed might not have increased still further is a point which the shortness of the stage alone prevented our ascertaining. We do not, however, wish it to be supposed that this Engine would take three times the weight at one-third the speed, or $34\frac{1}{2} \times 3 = 103\frac{1}{2}$ tons at 4 miles an hour, because it was made expressly for 12 miles an hour. There is, in all Engines, a certain speed for the piston, at which a maximum effect is produced, and, if not strictly adhered to, a proportionate reduction in the effect will be the consequence; and, therefore, to adopt such a plan of calculation would be as unfit and as erroneous as that of supposing the speed of the Darlington Engines increased to 10 miles an hour, and giving the result as the effect to be produced at that speed.

To give an example:—On the Railway, near Liverpool, an Engine was employed for drawing the waggons loaded with marle. Its general load was about 70 tons (exclusive of its own weight), which it moved at the rate of about 5½ miles an hour; but when detached, and having only its own weight to move, we found that it was incapable of maintaining a speed of 20 miles an hour. But if the theory of proportioning the load inversely, as the velocity, as adopted by Mr. Walker, had been correct, the Engine ought to have taken 12½ tons at that speed. Also, the performance of the "Rocket" Engine, at 13 miles an hour, was found to be 37¼ tons gross, and at 35 miles an hour the weight of the Engine was its load; but, according to the same rule, it ought to have taken 9½ tons.

From the experiments which have been detailed, it is evident that, on a level Railway, a Locomotive Engine, weighing from 4 to 5 tons, will convey 20 tons of goods, exclusive of carriages, at the rate of 12 miles per hour; and that on the Rainhill and Sutton planes, which are each 1½ mile long, ascending 1 in 96, the same Engine will draw 8 tons of goods at 10 miles an hour. The force, therefore, which the Engine has to exert at those speeds on the level, and on the inclined plane, is respectively 497 lbs. and 656 lbs.

If we calculate the effect which a Locomotive

Engine is capable of producing at 10 miles per hour, having two 10-inch cylinders, with pistons, moving 180 feet per minute, and an effective pressure of 25 lbs. per square inch (being one half the elasticity of steam in the boiler), we shall have 157 inches area of the cylinders × 25 lbs. × 180 feet ÷ 880 feet per minute (being 10 miles per hour) = 803 lbs. the power of the Engine, which exceeds the resistance of 8 tons of goods, on a plane ascending 1 in 96, by 147 lbs.: hence the Engines are fully adequate to the load assigned.

Since the Engines are proved to be more than equal to the resistance of 656 lbs. and proposed to work at this, it may seem inconsistent to apply a load on the level, the resistance of which only amounts 497 lbs.

Experience, however, has shown, that though a Locomotive Engine may be constructed capable of overcoming a certain resistance, where unavoidable and peculiar local impediments render it expedient, it is injudicious to work regularly with a load that approximates so nearly to the utmost effect of which it is susceptible. This is the reason why the load has been so apportioned on the inclined planes and on the level; that on the former being 656 lbs. and on the latter only 497 lbs.

The load for the Locomotive Engines on the Liverpool and Manchester Railway is therefore taken at 20 tons, except at Rainhill and Sutton, where assistant Locomotive Engines will be required, each capable of ascending with 12 tons of goods at 10 miles per hour.

Admitting, as it is in Mr. Walker's report, that each Engine will make three journeys daily between

Liverpool and Manchester, we shall have the work of one Engine, equal to 20 tons of goods, conveyed over 90 miles, or 1800 tons conveyed over one mile.

The daily traffic being stated at 4000 tons conveyed 30 miles, or 120,000 tons conveyed one mile, will consequently require 67 Engines to perform the work.

The assistant Engines requisite at Rainhill and Sutton planes being estimated equal to $\frac{12}{20}$ths of the load on the level, the daily work to be performed by them will be $\frac{4000 \times 12}{20} = 2400$ tons.

Each Engine, when fully employed, may safely be calculated to make 20 journeys, or 60 miles per day, which is equal to 240 tons. Hence 2400 tons will require 10 assistant Engines, making 77 the number constantly at work, to convey daily 2000 tons in each direction between Liverpool and Manchester; to which must be added, $\frac{1}{5}$th for spare Engines: the total number therefore, will be 93.

ESTIMATE OF CAPITAL REQUIRED.

93 Engines and Tenders, at £600	£55,800
4 Water Stations at £500	2,000
Crossings at the Rainhill and Sutton inclined planes, for the assistant Engines to pass from one line of road to the other	200
Total capital	£58,000

ESTIMATE OF THE ANNUAL COST OF EACH ENGINE.

One Engine and Tender will cost	£600
Add $\frac{1}{5}$th for spare Engine and Tender	120
Whole cost of 1 Engine at work	£720 0 0

Interest of capital, including depreciation, at 7½ per cent.				£54	0	0
Add annual repairs, as ascertained by actual observation, on the Springwell and Darlington Railways				50	0	0
Wages, Coals, and other expenses, as follows:—						
Engine Man's wages, at 21s. per week	£54	12	0			
Assistant	26	0	0			
Coals.—1 Engine has been stated to convey 1800 tons over 1 mile per day, which at 1.75 lbs. per ton per mile, is 3150 lbs. per day, or, taking 312 working days in one year, is 439 tons per year, at 5s. 10d.	128	0	10			
Grease, oil, hemp, &c.	12	0	0			
				220	12	10
Annual cost of working 1 Engine				£324	12	10

ANNUAL COST OF WATER STATIONS.

Interest and depreciation on original cost of each Water Station, viz. £500, at 7½ per cent.	£37	10	0
Annual repairs, grease, &c.	5	0	0
Coals for each Station, 100 tons at 4s. 6d.	22	10	0
Attendant	39	0	0
Cost of 1 Station	£104	0	0

Annual cost of leading 2000 tons of goods per day each way between Liverpool and Manchester:—

Annual cost of working 77 Engines, at £324. 12s. 10d.	£24,997	8	2
Annual cost of five Water Stations, at £104. each...	520	0	0
	£25,517	8	2

This sum divided by 4000 tons, conveyed over 30 miles per day, or for 312 days, equal 37,440,000 tons conveyed over 1 mile, gives the cost at 0.164 of a penny per ton per mile, or $4\frac{9}{10}$ pence for the whole distance.

The method of drawing goods on Railways by means of Fixed Engines and ropes, called the "reciprocating plan of conveyance," was said to be invented by Mr. Thompson, who took out a patent for the improvement.

The plan consists in placing Steam Engines at intervals of one or one and a half mile along the whole line of Railway, and having ropes running on rollers, placed between the rails, to extend from one Engine to the other, by which the waggons are drawn forward. When a train of waggons leaves a station, it takes along with it another rope, technically called the "*tail rope,*" which serves to bring back the next train which is moving in the contrary direction; the rope which drew the first train then becomes the "*tail rope,*" and is drawn back by the former, which then becomes the "*head rope.*" This is called the reciprocating system.

As the application of this kind of power is at present very limited, there is necessarily a want of experience as to its practicability, where despatch and regularity are indispensable.

There can, however, be no doubt but that a speed of 10 or 12 miles an hour, or even more, may be maintained during the time the carriages are in motion; but whether the stoppages in changing ropes and crossing from one way to the other at the Engine stations may not reduce the average speed very considerably, is a point on which we shall offer a few remarks.

The Brunton and Shields Railway has five continuous planes worked by Fixed Engines, only one of which may be said to be on the reciprocating plan; for on three of the planes the loaded waggons run of themselves, and the rope is merely used to draw back the empty ones; and on the other the full waggons are drawn up, and the empty ones run back with the rope: from which it appears, that on four of the planes it is only necessary to use one rope, the gravity of the waggons dispensing with the other.

This mode is highly advantageous, in point of simplicity and economy, when compared with the reciprocating system, where two ropes to each train are required.

The Brunton and Shields Railway has only a single line of rails with a passing place at the Engine stations; but, on the Liverpool road, two lines would be required to be worked by the same Engine, which consequently lessens the simplicity still further.

Mr. Walker has shown a plan,* by which the waggons and ropes are to be managed at the stations, which, if not altogether impracticable, is certainly very complex; but this may arise, in some degree, from the nature of the machinery consequent upon the system, and not entirely upon the peculiar plan which Mr. Walker has proposed.

---

* Mr. Walker, in a note in the second edition of his Report, says this plan is not his own, but was struck out by Mr. Rastrick.

To explain this by example:—The diagram, No. 2, shows two trains of waggons being drawn towards the station. The train *d* having to take the switches at *e* to cross into the other road, necessarily comes in contact with the rope from the roll, No. 2, which is out at the next station. The same obstruction arises to the train *c* by the rope which is out at the station in the opposite direction.

To remedy this, the ropes might be carried on frame-work above the loaded waggons, as far as where the latter would pass the switches; but even in that case, the rope, in drawing a train towards any station, would require to be detached on arriving at the frame-work, and the impetus of the waggons would not carry themselves and the tail-rope through the switches to the place where the next rope would have to be attached.

There are several methods of arranging the rope-rollers for this system, which have objections more or less important, any of which will require a much greater stoppage of the train at the stations than has been calculated upon.

We are convinced of the truth of this, from an investigation which we made last year of the relative rates of speed on the Brunton Railway, just referred to, which was embodied in one of Mr. Stephenson's reports on the same subject.

In commencing from that part of the Railway adjoining the river, we intended to have given a statement of the speed on each plane; but, owing to the wind being so very high, and the empty waggons not running freely on some of the planes, we were obliged to wait for a considerable time at the stations, and we therefore took little notice in passing up, further than that we were nearly two hours in going 5 miles and 193 yards.

In returning with a gross load of 31 tons, we had the wind in our favour, and the following is the result of the experiment:—

	Yards long.		*Time.*	*Stoppages.*
First Plane...............	1287	in	5′ 10″	8′ 20″
Second ditto	2316	in	7′ 30″	4′ 30″
Third ditto.......	1562	in	6′ 30″	6′ 00″
Fourth ditto	1760	in	6′ 00″	5′ 00″
Fifth ditto.	2068	in	5′ 10″	0′ 00″
5⅛ miles.	8993	in	30′ 20″	23′ 50″

From this it appears, that during the time the waggons were in motion a speed of upwards of 10 miles an hour was maintained, which, by taking into account the stoppages for changing ropes, &c. is reduced to 5⅔ miles an hour. These stoppages, however, would not have been so much if the Engines had been sufficiently powerful to draw both ways at a time, as would be the case on the Liverpool and Manchester Railway; but this advantage may very likely be counterbalanced by the complication in the machinery necessary to work two lines of road.

We agree nevertheless with Mr. Walker that 2½ minutes for changing the ropes, &c. is amply sufficient where despatch is requisite; but who can look upon 30 miles of Railway, divided into equal stages, with 40 trains of carriages, moving at the rate of 12 miles an hour, and drawn by 20 different Steam Engines (a delay in any one of which would stop the whole), without feeling that the liability to derangement alone is sufficient to render the stoppages extremely uncertain? And in considering this long chain of connected power, given out by so many machines, with the continual crossings of the trains from one line to the other, and subject to the government of no fewer than 150 men, whose individual attention is requisite to preserve the communication between two of the most important towns in the kingdom, we cannot but express our decided conviction that a system which necessarily involves, by a single accident, the stoppages of the whole, is totally unfitted for a public Railway. We have hitherto spoken of general disadvantages, but what inconvenience would individuals not suffer, on arriving at any particular point find that from some accident, which might have occurred several miles off, they were compelled to stop, without knowing the cause of the delay, and without a chance of any other carriage coming up to take them forward?

Mr. Walker has compared this system to "a chain "extending from Liverpool to Manchester, the failure "of one link of which would derange the whole." But he adds—"there are about 20 changes of horses "in the mail between London and Liverpool, a stop-"page at any one of which influences the whole; re-"verting to our metaphor, the chain here extends for "two hundred miles, and notwithstanding the various "chances of accidents and delays, the mail generally "arrives about the proper time."

We do not see the comparison so strikingly as Mr.

Walker seems to have done, for when an accident happens to a horse in the mail, another is generally brought to supply its place; but it would be impossible to supply the place of a 50 horse Steam Engine with the same facility. But to place the two cases in a parallel position it would stand thus:—In case of accident to an Engine or a rope, every train between Liverpool and Manchester would be stopped until the injury was repaired. So would it be with an accident with the mail, every coach, and cart between Liverpool and London would be delayed, but as this sympathy does not exist, Mr. Walker's metaphor is quite inapplicable.

It ought not, however, to be inferred that we deem this mode of conveyance to be more liable to accidents than that by Locomotives; but it must be admitted that an accident occurring to a Locomotive Engine only stops the particular train of carriages which is attached to it, and may, therefore, be considered only a partial delay, whereas a derangement in the reciprocating system, as we have already shown, creates a general stoppage.

In estimating the cost of conveying goods by means of Fixed Engines, the friction and the wear of ropes become the most important considerations.

The friction of ropes on a level Railway has hitherto been but very partially understood, owing to the difficulty of making experiments for the purpose of ascertaining it. Mr. Walker has given two experiments, whereby he shows that the amount of friction is equal to $\frac{1}{35}$ of the weight of the rope; but as he has not given the weights of the waggons, nor the inclination of the road, on which the experiments were made, we are unable to ascertain whether this deduction is correct. We allude to this more particularly, because in experimenting for this purpose, the gravity of the rope itself has been almost universally neglected. In the experiments made by Mr. Wood, he has given the friction of ropes on inclined planes of various rates of inclination, but his results can only apply to such planes as those on which the experiments were performed, because the gravity of the rope was not considered a part of the accelerating force.

The method which we adopted in investigating this part of the subject, was by placing so many empty waggons on an inclined plane as would move a given length of rope at an uniform velocity; this being ascertained, it is evident that the gravity of the rope and waggons will be equal to their friction.

EXPERIMENT FIRST.—Three waggons, weighing 72 cwt. maintained a speed of 1½ mile an hour, with 930 yards of rope, weighing 3397 lbs., on a plane ascending 1 in 33.

EXPERIMENT SECOND.—Four waggons, weighing 96 cwt. maintained the same speed, with 1370 yards of rope, weighing 5004 lbs.

EXPERIMENT THIRD.—Five waggons, weighing 6 tons, maintained a speed of 1⅚ mile an hour, with 1810 yards of rope, weighing 6600 lbs.

To reduce these to fractional parts of the rope's weight—

1st. Gravity of waggons....244½ lbs.
Gravity of rope ......103 „
347½ „
Deduct friction of waggons.. 39 „
Leaves 308½ „ or $\frac{1}{12}$ of the weight of the rope for its friction.

2d. Gravity of waggons....326 lbs.
Gravity of rope ......152 „
478
Deduct friction of waggons... 52 „
Leaves 426 „ or nearly $\frac{1}{12}$

3d. Gravity of waggons... 407½ lbs.
Gravity of rope .....200 „
607½ „
Deduct friction of waggons... 65 „
Leaves 542½ „ or nearly $\frac{1}{12}$

There is in this result a material difference with that of Mr. Walker, who states the friction at $\frac{1}{22}$, but as our experiments were made with the greatest care, we cannot but think the result very nearly correct.

But to show how much the weather, and consequent state of the roads, affect such experiments, we quote the following from Mr. Wood. Speaking of a Fixed Engine plane having an inclination of 1 in 75 nearly, he says—

"When regularly at work, this Engine drags 12 "loaded carriages up this plane, and the rope is taken "out again by the empty carriages descending the "plane. In bad weather that number is not sufficient "to accomplish it, and a horse is obliged to be "constantly kept at the Engine, to assist the carriages "in overcoming the resistance of the rope."*

If, therefore, these twelve waggons, each weighing 3080 lbs. cease to move near the bottom of the plane, where the friction of the rope is at its maximum, we shall have for the gravity of the waggons

3080 × 12 ÷ 75 = 492 lbs.
And for the gravity of the rope 3527 ÷ 75 = 47 „

539 „
From which deduct friction of waggons.........180 „

Leaves for the friction..................................359 lbs.

which is rather more than $\frac{1}{10}$th of the weight. It would evidently be very injudicious to calculate the power of Fixed Engines on the assumption that the friction of the rope is only $\frac{1}{22}$d of its weight, when the changes in the weather very often increase it to more than double that amount.

It is well known that the Engines erected on the Brunton Railway were found to be inadequate to perform the work, which we believe to have arisen

---

[*] Treatise on Rail-roads, page 213.

entirely from an imperfect knowledge of the power requisite to move the rope.

The load which Mr. Walker has assigned to be conveyed by each Engine is 52 tons, to be dragged by a rope 3½ inches in circumference; and, before estimating the cost, it will be necessary to examine whether such a size is adequate to such a load.

In this, as in most other cases, we can only refer to those Railways where similarity of circumstances will warrant a comparison. The resistance of 52 tons will be 582½ lbs.

On the Hetton Railway, a 5-inch rope is used to drag 24 empty waggons, each weighing 28 cwt. up an ascent of 1 in 250. On this plane a 3½-inch rope was originally used, but it was so frequently broken that it was removed in four months.

Then 3136 × 24 ÷ 250 = 301 lbs. gravity,
And 3136 × 24 ÷ 200 = 376 „ friction,

Resistance requiring a 5-inch rope...677 „

On another plane, which is quite level, a rope 4½ inches in circumference is used to drag the same number of waggons; consequently, 3136 × 24 ÷ 200 = 376 lbs. the resistance requisite for a 4½ inch rope; and, by reducing these to the resistance of 52 tons on a level, we shall have by the former for the requisite size of the Rope..................4.6 inches

By the latter...5.6 „

In the foregoing we have not taken the weight of the rope into calculation, as the length of the planes are nearly alike.

We are aware that on the Brunton Railway ropes lighter than those at Hetton are used; but, since there are no level planes worked by this method at Brunton, we think the deductions from Hetton better data.

But although the ropes used at Brunton are lighter than those which we should propose on the Liverpool line, it should not be inferred that the strain on the former is equal to that on the latter.

For example:—On two planes, where 3¼-inch ropes are used to draw back the empty waggons, the full ones running down by their own gravity, the rise being 1 in 120 and 1 in 123 respectively; if we take it at 1 in 122, we shall have for the resistance of 12 tons of waggons equal to 354 lbs. which is not quite two-thirds of the resistance of 52 tons on a level.

The breakage of ropes at Brunton has been very frequent, which, on a Railway where comparatively little traffic is carried on, may not cause much delay. We recollect noticing *twenty-seven splices*, or places where it had been broken in one rope, and there were several others which showed evident marks of being overstrained.

On the Hetton Railway a very considerable trade is carried on, and a stoppage would consequently be a serious loss: it is very probable that the substitution of a 5-inch for a 3½-inch rope was occasioned by the delays arising from the breakage of the latter.

It is clear, therefore, that for such a line of Railway as the Liverpool and Manchester a rope of 3½ inches in circumference is too small; and, in order to prevent as much as possible those delays arising from breakage, a 4½-inch rope is the very least in size that should be used; and on the inclined planes a rope not less than 5½ inches.

In comparing the two systems of conveyance, the consumption of ropes is a very material point; and in considering it, Mr. Walker observes that experience ought to be our guide.

There can be no doubt that experience is the safest criterion in cases of this description, but great care is requisite in transferring the results from any particular Railway to another not similarly situated.

The Brunton and Shields Railway, on which the cost of ropes is said not to exceed $\frac{1}{20}$th of a penny per ton of goods per mile, is extremely favourable; but the chief portion of this line descends gradually with the load, and in favourable weather the reciprocating system is adopted on one plane only. The data, therefore, afforded by this Railway cannot apply to the Liverpool and Manchester, where the whole is supposed level, or nearly so.

The next instance which Mr. Walker adduces as a guide, is a Stationary Engine on the Darlington Railway, at Brusselton, which works two planes, one ascending 1 in 33, and the other descending with the load 1 in 30. The cost of ropes is here stated to amount to ¼d. per ton of goods per mile.

To determine from this data the cost of ropes on a level Railway, a mode of calculation is adopted at variance with every-day's experience.

The average load upon the Brusselton planes is reduced to a level, and the cost reduced in the same ratio, without considering that the wear of ropes upon Railways is very materially influenced by starting or putting into motion the train of waggons at the bottom of the planes. Now the resistance to be overcome by the rope, when carriages are in uniform motion, is much less than at the starting of the train, arising not merely from the friction of the axles being augmented by the adhesion between the axle and bush, when the waggons are in a state of rest, but also from the vis-inertiæ of the mass to be moved. Every one experienced with the operations of Stationary Engines on Railways can bear testimony that the breakage of ropes is mainly occasioned by the starting of the trains.

On the Brusselton, as well as on inclined planes generally, the bottom is made level, and sometimes descending in the direction of the load, in order that gravity may aid the rope in giving motion to the train; but, notwithstanding these judicious precautions, the rope receives the greatest injury at starting, which of course exists to as great an extent on level Railways as on inclined planes, which are made flat at the bottom.

The deductions drawn from the latter, omitting this consideration, are therefore totally inapplicable and useless as a guide in determining the strength of ropes requisite on level planes. This view will show that the cost of ropes on inclined planes is a much nearer approximation to that on a level Railway, when large trains are employed, than is generally apprehended, and that the wear is far from being directly as the load.

The last instance to which Mr. Walker refers in his Report as affording data on this important point, is on a part of the Hetton Railway, which is nearly level, where " 301,800 tons are conveyed over $2\frac{1}{2}$ miles for an expense of £780. in ropes, which gives, according to the most favourable mode of calculating, $\frac{13}{100}$ of a penny per ton per mile.

This part of the Hetton road is worked by the reciprocating system to a greater extent than on the Brunton and Shields, and the planes not varying widely from a level, is better data than either of the others; yet it does not seem to have influenced Mr. Walker's conclusions on this point, having fixed on $\frac{8}{100}$ of a penny per ton per mile, whereas the daily experience at Hetton indicates $\frac{13}{100}$ths.

Since, however, the curves which exist on that line may increase the wear of ropes in some degree, we shall take the cost, when applied to the Liverpool and Manchester, at $\frac{10}{100}$ of a penny per ton per mile.

It appears that the accounts which gave $\frac{1}{20}$ of a penny per ton per mile on the Brunton and Shields road, were founded upon the assumption, " that (excepting " three ropes which had been actually worn out) those " in use would do about half as much more as they " had already done,"—a method of calculating quite inadmissible.

There exists another powerful reason why the cost of ropes on the Brunton Railway should not be followed as a guide in making estimates in reference to the Liverpool and Manchester, viz. the different planes do not only ascend and descend in the same direction with the load, but also with different degrees of inclination. This being the case, when a rope becomes insufficient for the ascending planes with the load, it is not rendered useless, but may be applied to some of the planes in succession, as the inclination decreases, or where the empty waggons alone ascend: thus a rope may be employed much beyond the period that it would be serviceable on a line of road on which it was proposed to convey a gross weight of 52 tons in each train, and over a series of planes, scarcely differing from a level or from each other. A rope, when unserviceable for one plane, would be equally so for the whole distance.

Before entering into an examination of the requisite powers of the Engines, it will be necessary to divide the line into stages, which, for the sake of perspicuity, we adopt those proposed by Mr. Walker.

" The space between the Liverpool tunnel and the " foot of Rainhill plane, about six miles in length, is " divided into four spaces, each 1½ mile long;—the " ascending and descending planes each to form one " stage;—the two miles level upon Rainhill two " stages;—and the 19 miles, from the foot of the plane " to Manchester, to be divided into twelve stages of " 1½ mile each, and one stage of one mile nearest to " Manchester."

The speed, when in motion, is proposed to be 12 miles an hour, which, including stoppages, will be reduced to 9 miles an hour between the two extreme points.

The power of the Engines on the 1½ mile stages will be thus:—

Friction of 52 tons at $\frac{1}{200}$ .... = 582 lbs.
Friction of 1½ mile of 4½-inch rope, weighing
6888 lbs. at $\frac{1}{12}$th............... .... = 574 „
1156 „

Power of a horse at 12 miles an hour = 150 × 2½ ÷ 12 = 31 lbs.: then 1156 ÷ 31 = 37 horse power; or, allowing for spare power, say 40 horses for one line, or 80 horses for two lines.

Power of Engines for the one mile stages:—

Friction of 52 tons, as above...................... ..... 582 lbs.
Friction of the one mile of rope, being two-thirds of the above..................... .... 382 „
964 „

But, since these Engines need not be made to propel the goods at more than 8 miles an hour, because the space of 1 mile can only be travelled over in the same time that the others are moving 1½ mile (on account of the necessary dependence of these Engines upon the others); therefore, the power of a horse at 8 miles an hour will be 150 × 2½ ÷ 8 = 47 lbs. which, divided into 964, gives the power of these Engines = 20½ horses, or for spare power 24 horses, or double that for the two lines.

The power of the Engines to work the two inclined planes will be—

52 tons ÷ 96 gives for gravity.................. 1213 lbs.
52 tons ÷ 200 gives for friction .... 582 „
Friction of rope ($5\frac{1}{2}$ inches circumference), 10,700 lbs. ÷ 12 = 891 „
Gravity of rope............ 10,700 lbs. ÷ 96 = 111 „

2797 „

2797 lbs. ÷ (31 power of a horse at 12 miles) = 90 horses.

This would be the power of the Engines in case no descending train was passing down the plane at the same time, but which, according to the regularity of the system, becomes a necessary consequence. We shall therefore assume the power requisite to work these planes, and the one-mile stages, to be 80 horses.

The power of the Engine at the foot of the inclined planes will, by allowing 10 horses to assist in overcoming the friction of the rope, be 50 horses, and the extra power at the tunnel 40 horses,

The total quantity of power will therefore be—

17	Engines	of 80 horses' power..............	1360	horses,
1	ditto	at the tunnel, 40..................	40	„
1	ditto	on level at Rainhill, 48..........	48	„
2	ditto	at the bottom of planes, 50....	100	„
1	ditto	at Manchester, 24................	24	„
		Total.............	1572	„

ESTIMATE OF CAPITAL REQUIRED FOR ENGINES AND MACHINERY.

One Engine of 80 horses' power	£2800	
Four Rope Rolls and Machinery	550	
Engine-house and Chimney	650	
Dwelling-house, Reservoirs, &c.	200	
	£4200	
Seventeen Stations at £4200		£71,400
Extra power at the Tunnel, 40 horses		1,800
One Engine of 48 horses' power	£1600	
Rope Rolls	500	
Engine-house and Chimney	600	
Dwelling-house and Reservoir	180	
		2,880
Two Engines at bottom of planes, 50 horses, same as last		5,760
One Engine at Manchester, 24 horses	£960	
Rope Rolls	250	
Engine-house, &c.	500	
Dwelling-house, Reservoir, &c.	180	
		1,890
Sheaves for Ropes, 13,090, at 12s.		7,854
Four sets of Crossings and Turn-outs at each station, 88, at £50		4,400
		£95,984

ANNUAL EXPENSE OF STATIONARY ENGINES.

Interest and depreciation on £95,984. at the rate of 6½ per cent	£6238	19	2
Coals for Engines, being altogether 1572 horse power, working 10 hours per day for 312 days, at 17 lbs. per horse power per hour = 37,222 tons, at 4s. 6d.	8374	19	0
Repairs of Engines and Machinery, including Fire Bars, Boilers, Hemp, Oil, &c. at £1. per horse power per annum	1572	0	0
43 Engine men, at £54. 12s.	£2347	16	0
21 Assistants, at £40	840	0	0
42 Brakemen, at £40. per annum	1680	0	0
84 men to ride the trains, being one man to each rope, at £40. per annum	3360	0	0
Wear and tear of Rope Sheaves, at £8. per mile of double way	240	0	0
Oil for Sheaves, 2100 gallons, at 2s. 6d	262	10	0
Eight men to oil sheaves, at £30. per annum	240	0	0
Annual cost of keeping the Machinery in working order	£25,156	4	2

ROPES.

108 miles of 4½-inch Rope on the level stages = 221⅓ tons (after deducting value of old material), at £42. per ton	£9296	0	0
Six miles of 5½-inch Head Rope for inclined planes, $19\frac{1}{10}$ tons, at £42	802	4	0
Six miles of 3½-inch Tail Rope for inclined planes, 7 tons 17 cwt. at £42	329	14	0
Grooves for Ropes crossing roads, 30, at £10	300	0	0
	£10,727	18	0

WEAR OF ROPES.

Interest on the above cost, at 5 per cent. per annum...	£536	7	10
Although the wear and tear on ascending the inclined planes will be increased, there will be a saving in descending, and we therefore take 30 miles at $\frac{1}{10}$th of a penny per ton per mile, on 4000 tons conveyed daily, equal to 37,440,000 tons over one mile per annum.........	15,600	0	0
Annual cost of Ropes, &c...............	£16,136	7	10

DUPLICATE ROPES, &c.

108 miles of spare 4½-inch Rope, 221⅓ tons, at £51...	£11,288	0	0
Six miles of 5½-inch Head Rope for inclined planes, 19$\frac{1}{10}$ tons, at £51.	974	2	0
Six miles of 3½-inch Tail Rope for inclined planes, 7 tons 17 cwt. at £51................................	400	7	0
Duplicates for Engines, at the rate of £1. per horse power.............	1,572	0	0
Signal Stations, 22, at £25.............	550	0	0
	£14,784	9	0
Interest on this amount at 5 per cent. per annum, being the annual cost of Duplicates, &c..........	£739	4	5

SUMMARY OF ANNUAL EXPENSE OF ENGINES, ROPES, DUPLICATES, &c.

Engines, being equal to 1572 horses	£25,156	4	2
Ropes.........	16,136	7	10
Duplicates, &c.	739	4	5
	£42,031	16	5

Which, divided into 37,440,000, the number of tons conveyed over one mile annually, will leave .02694 of a penny per ton per mile, and the capital invested in this establishment will be—

Engines and Machinery	£95,984	0	0
Ropes, &c. in use	10,727	18	0
Duplicate Ropes and Machinery	14,784	9	0
	£121,496	7	0

To compare the two estimates in one view—

The capital required to convey 2000 tons each way per day by Locomotive Engines, will be	£58,000	0	0
And by Stationary Engines	121,496	7	0
Difference in favour of Locomotives	£63,496	7	0

The annual cost of conveying the same quantity by Locomotive Engines	£25,517	8	2
And by Stationary Engines	42,031	16	5
Annual saving in favour of Locomotives	£16,514	8	3

The rate per ton per mile by the Locomotive system
is..0.164 of a penny,
and by the Stationary plan..............0.269 „
making an excess of expense per ton per mile of 0.105 of a penny by the Stationary system; or the proportionate advantage is as 8 to 5 in favour of Locomotive Engines.

We have not thought it necessary to include any contingent expenses which may be common to both systems, and we have made our calculations on the supposition that the trade be quite regular and uniform from one end of the line to the other.

These conclusions, considered in connection with the Liverpool and Manchester Railway, we believe are fully borne out by experience, especially when the disadvantages to which the Locomotive system has been exposed in its application to practice are attentively and impartially weighed. Until within a short period, Railways have been principally employed for the conveyance of coal or other mineral, from mines to an eligible shipping place, and, since mines either become wholly or partially exhausted in a few years, it is essential, in constructing Railways for such purposes, to study economy in the first outlay. This necessity, combined with a want of information on the great importance of reducing the irregularities of the natural surface of the ground to obtain a uniform section, has tended much to retard the progress of Locomotive Engines.

When they were first introduced in the north of England, they were either very imperfectly constructed or were applied to situations not adapted for their profitable employment. The Colliery Railways in the north have rarely been constructed with a due regard to the best sectional line, so that the greatest effect might be produced with the least expenditure of power; they more generally present ascents and descents, to an extent that render both horses and Locomotive Engines almost useless. Hence we perceive why the introduction of Locomotive Engines has been so tardy and so frequently attended with unfavourable results. Such failures are imagined by many to arise from imperfections concomitant with the system itself, whereas they have really arisen from a misconception of their capabilities when properly brought into operation, and particularly from a want of discrimination in determining the limits, beyond which they become expensive and troublesome.

In drawing a comparison between Locomotive and Stationary Engines, as applicable to the Liverpool and Manchester Railway, the relative expense is certainly of vast importance; but though this is a primary object, that of despatch and public accommodation are of the utmost consequence, and may be said to rank higher in the scale of importance than expense, when the difference between the two systems in the latter item is not very great. When the traffic upon a Railway is either small or variable, the Locomotive Engines are not only cheaper but much more convenient, because the number of Engines in operation at one time may be regulated as the trade fluctuates; but when the Stationary system is adopted, the whole of the machinery must be employed to convey the goods, however trifling. Where the trade is great and nearly uniform, as is the case between Liverpool and Manchester, the expense of the Stationary system approximates probably more nearly to that of the Locomotive than in any other locality in England. It is in this instance, therefore, that despatch and public accommodation claim particular attention.

In this respect Mr. Walker is of opinion that either system is fully adequate; but he does not appear to have duly considered the practical difficulties which are unavoidable where a chain of Stationary Engines is employed. Locomotive Engines may be compared to horses, as far as convenience is concerned, with this advantage, that they are much more manageable, because each Engine is an independent power: but the case is widely different in the other system, where the whole is dependent on each individual part, and also upon a series of regulations, liable to be deranged by the inattention of workmen. With the Locomotive Engines the carelessness of one person extends, in most cases, only to one train of carriages; whereas an accident produced by the same cause with Stationary Engines occasions a delay from one end of the road to the other, and the risk of accident is evidently proportionate to the length of the line of road. We may go so far as to conceive a line of Railway, with Stationary Engines, so long, that accidents would be almost perpetually occurring, which leads to the inference, that the conveyance of a large quantity of goods by such a series of Engines and ropes would, in the end, become *actually impracticable.*

This latter supposition is not advanced as applicable to the Liverpool and Manchester Railway, but merely to show, in a conclusive manner, that despatch and public accommodation would be obtained by such a system with much greater difficulty in that line of road than upon any other hitherto constructed.

It must be admitted that accidents with Engines applies with equal force to both systems, but accidents with the ropes are the most general sources of delay, from which the Locomotive system is entirely free. When a line of rope always occupies the centre of the Railway, it is almost absolutely necessary, to prevent accidents at the crossings of turnpike roads, that the level of the Railway should either be considerably above or below the common road, to admit of bridges being constructed. This creates an increase in the original outlay, which may in some instances be very serious, if not nearly impracticable. Mr. Walker, with a view to avoid the Railway carriages coming into contact with carts on the common roads, where they cross on the same level, proposes to attach what are technically called "friction clutches" to the Engines, so that the trains may be stopped by powerful brakes when necessary, whilst the Engines and the other trains continue to move at the regular velocity. This expedient is certainly practicable, but it would injure the ropes very seriously when the requisite force is applied by the brakes to stop the train of carriages, because the friction of the clutch must greatly exceed the resistance of the train, since it must be more than sufficient to give motion to them from a state of rest at each station. The inconvenience from such an adaptation of friction clutches would not stop here, but would give rise to an irregularity at each Engine station, from the trains, moving in opposite directions, not arriving at the same instant of time, which is certainly necessary to secure that despatch which Mr. Walker calculates upon in other parts of his Report.

Another contrivance is suggested, viz. :—" By con-
" necting the head and tail ropes together under the
" train, by a contrivance instantly to disengage the
" train from the rope, and by proper signals of ap-
" proach, any chance of accident to persons or cattle
" crossing would be very much lessened."

We either do not understand Mr. Walker's idea, from the explanation he has given, or it is quite impossible to carry the suggestion into effect.

If the head and tail ropes are connected under the train, they will continue to move after the train is disengaged, and will continue to do so though the train may be brought to rest; therefore the junction of the head and tail ropes cannot be replaced under the train, but will arrive at the station before it. This being the case, instead of disconnecting the head and tail ropes from each other at the station, the Engine must continue to wind the tail rope on the drum until the train arrives, or the ropes must be disengaged, and the train brought forward by manual labour or horses, wherever it may be situated, to the Engine station.

This never can have been contemplated by Mr. Walker; indeed without an endless rope, the train cannot be disengaged during the passage from station to station.

The conveyance of intelligence, from one Engine to another, in the Stationary system, is liable to be interrupted by foggy weather when telegraphs are adopted. Bells are sometimes resorted to, but their operation is also uncertain, being influenced by the direction and strength of the wind. The necessary intelligence may also be conveyed from one station to the other by attaching the tail-rope to the train, and applying the Engine to drag it, together with the head-rope, in a contrary direction: this gives motion to the drum at the adjoining station, and signifies that the carriages are ready for proceeding.

Though this is the most certain method when the state of the atmosphere renders the common telegraph useless, it occupies too much time where despatch is of vital importance.

From the local situation of the Liverpool and Manchester Railway, it is evident that, in a very few years, several branches from the various towns on each side will join the main line. Hence the traffic on the different parts of the line will annually undergo some modification. If, however, the Stationary system were established in the outset, it would be necessary to construct the Engines of sufficient power to meet any probable increase of this kind. If the Engines were not possessed of such extra power, and only made adequate to the trade already contemplated to exist between the ends of the line, it is evident that much personal inconvenience, as well as a positive detriment to the trade, would be experienced.

We allude to this to show that much difficulty would arise in adjusting the powers of the Engines requisite for the different parts of the line of road between Liverpool and Manchester, excepting, indeed, they were all made very powerful to meet any future increase of trade. If such a provision were not made, we may suppose that goods from one end of the line is equal to the full performance of the Engines; in this case, the goods from any intervening town or branch-line must be detained until the more distant trade subsides. It is unnecessary to make any comment on the consequences of such a detention.

Wherever the Stationary system is adopted, it is evident that every branch-road must form a junction at an Engine station, which will very frequently cause a material increase of expenditure in the formation of such branch Railways, and, therefore, produce a corresponding increase in the cost of conveying goods from town to town. The whole of these difficulties, which are inseparable from the Stationary system, on a public line of road, where the trade must necessarily fluctuate, are easily and effectually obviated with Locomotive Engines, for should the trade in any part undergo a temporary increase or decrease, the requisite power may be immediately applied or withdrawn.

Many other practical considerations might be adduced to exemplify the great superiority of the Locomotive over the Stationary system on a public Railway, but they are of a description not easily understood or duly appreciated, except by those who have had experience and frequent opportunity of witnessing the daily operation of machinery on Railways. Obstacles often arise from casualties, which, by bare mention in this place, would appear frivolous, whereas to the practical man they are of importance, and tend to demonstrate that it is of great consequence to adopt a system, the efficient operation of which, as a whole, is not dependent on each individual part.

Account of the Competition of Locomotive Engines for a Premium of £500, offered by the Directors of the Liverpool and Manchester Railway Company, contested at Rainhill in October, 1829.

The intense interest excited by the offer of this premium was almost unparalleled; the friends of Locomotive Engines hailed it as an era which was to create one of the greatest changes in the internal communications of the kingdom that had ever yet taken place. The canal proprietors dreaded lest the issue of these trials should prove that a more economical mode of conveyance might be established; and the projectors of the Railway viewed the experiment as one calculated to make that grand work profitable to themselves and beneficial to the country, or show to them that an immense expenditure had been incurred which might otherwise have been avoided.

The public were not idle spectators: they considered the successful termination would not only confer individual benefits and local advantages, but a great national good, by introducing a system of conveyance throughout the country which is at once easy, safe, expeditious and economical, affording to the poor a luxury hitherto denied to them, and to the more opulent a despatch which hitherto no sum could purchase. There are few classes that such a change would not, in some degree, affect. A reduction in the price of coal may be said to affect all: the same may be said of a reduction in the rate of carriage, and particularly as it regards the manufacturer, who, as is generally the case in this country, is so internally situated, as to be compelled either to relinquish a portion of his profits, or lay an additional price on the manufactured article, on account of the expenses arising from conveyances. The facility afforded for conveying all kinds of agricultural produce, for bringing into cultivation those lands which, on account of their remote situations and want of proper communication, have been so long neglected.*

The enormous expense of maintaining such an establishment of coach-horses, as the increase of travelling within the last few years has so fearfully augmented, is a subject too serious to be overlooked,—to say nothing of the cruelties so often practised on these poor animals, and which tends so much to lessen those enjoyments which travelling would otherwise give. We need only consider the tax which such an establishment involves on the country, and then say, whether the introduction of Steam power is not "a consummation devoutly to be wished."

---

* The method now adopted for cultivating Chat Moss, by means of Railways, exemplifies this position most strikingly.

In a political as well as in a military point of view, we would also remark, that the facility of moving with great rapidity from one station to another, shows how a whole nation may be concentrated. Distance may very properly be estimated by the time required to traverse it: thus Liverpool may be said to be 4½ hours from Manchester, and 22 hours from London; but since 30 miles an hour has been found to be attainable, Manchester would only be 1¼ hour and London 7 hours from Liverpool. From this view of the subject, every town in the kingdom would be brought nearer to each other, and the whole civil or military force of England might be concentrated in any given point within the period of a few hours. The last, though not by any means the least important consideration, is the saving in time. It may be inferred that time spent by men of business in travelling from one place to another (except expressly for pleasure), is lost, because it is turned to no profitable account: thus a person who makes two journeys from Liverpool to Manchester and back in a week, spends on the road 18 hours, which might be accomplished in 5 hours, effecting a saving of 13 hours per week, which is no less than five years of his life. When these advantages are properly estimated, it will not appear surprising that these trials should have produced so general an interest.

The day fixed for the competition was the 1st of October, but, to allow the Engines sufficient time to get into good working order, the Directors extended it to the 6th. The following conditions were issued from the Board previously to the day of running:—

" *Railway Office, Liverpool, 25th April,* 1829.

" STIPULATIONS AND CONDITIONS

" *On which the Directors of the Liverpool and Manchester Railway offer*
" *a Premium of* £500. *for the most improved Locomotive Engine.*

" 1st. The said Engine must effectually consume its own smoke, according to the provisions of the Railway Act, 7th Geo. 4.

" 2d. The Engine, if it weighs six tons, must be capable of drawing after it, day by day, on a well-constructed Railway, on a level plane, a train of Carriages of the gross weight of twenty tons, including the Tender and Water Tank, at the rate of ten miles per hour, with a pressure of steam in the boiler not exceeding 50 lb. on the square inch.

" 3d. There must be two safety valves, one of which must be completely out of the reach or control of the Engine-man, and neither of which must be fastened down while the Engine is working.

" 4th. The Engine and Boiler must be supported on springs and rest on six wheels; and the height, from the ground to the top of the chimney, must not exceed fifteen feet.

" 5th. The weight of the Machine, with its complement of water in the boiler, must, at most, not exceed six tons; and a Machine of less weight will be preferred if it draw after it a proportionate weight; and if the weight of the Engine, &c. do not exceed five tons, then the gross weight to be drawn need not exceed fifteen tons, and in that proportion for Machines of still smaller weight, provided that the Engine, &c. shall still be on six wheels, unless the weight (as above) be reduced to four tons and a half or under, in which case the Boiler, &c. may be placed on four wheels. And the Company shall be at liberty to put the Boiler, Fire Tube, Cylinders, &c. to the test of a pressure of water, not exceeding 150 lbs. per square inch, without being answerable for any damage the Machine may receive in consequence.

" 6th. There must be a mercurial gauge affixed to the machine, with index rod, showing the steam pressure above 45 pounds per square inch, and constructed to blow out at a pressure of 60 pounds per inch.

" 7th. The Engine to be delivered complete for trial at the Liverpool end of the Railway, not later than the 1st of October next.

" 8th. The price of the Engine which may be accepted not to exceed £550. delivered on the Railway, and any Engine not approved to be taken back by the owner.

" N. B. The Railway Company will provide the Engine Tender with a supply of water and fuel for the experiment. The distance within the rails is four feet eight inches and a half."

The gentlemen appointed to be judges on this occasion were Mr. Wood, of Newcastle-upon-Tyne; Mr. Rastrick, of Stourbridge; and Mr. Kennedy, of Manchester.

The number of Engines entered for the prize was five, viz.:—

Owners.	*Name of Engines.*	*Weight.*
Mr. R. Stephenson	" The Rocket"	4 tons 5 cwt.
Messrs. Braithwaite and Ericsson	" The Novelty"	3 „ 1 „
Mr. Hackworth	" The Sans Pareil"	4 „ 15½ „
Mr. Brandreth's (Horse Machine)	" The Cycloped"	3 „ 0 „
Mr. Burstall	" The Perseverance"	2 „ 17 „

On the morning of the 6th the ground at Rainhill exhibited a very lively appearance; several thousand persons were collected from all parts of the country, amongst whom were several of the first Engineers of the day. A commodious tent had been erected for the accommodation of the ladies, which was graced by the beauty and fashion of the surrounding neighbourhood; the sides of the race-ground were lined with carriages of all descriptions;—in short, the *tout ensemble* exhibited as much bustle and excitement as if the great St. Leger had been about to be contested.

The ***Rocket*** of Mr. Stephenson was first called out. This Engine is placed on four wheels. The boiler is cylindrical, having 25 tubes passing directly through it, for the purpose of conveying the heated air from the fire which is contained in a "fire-box" attached to one end of the boiler. The cylinders are fixed on the sides of the boiler, and work diagonally to the outside of the two fore-wheels of the Engine. These wheels are 4 feet 8 inches in diameter; those on which the "fire-box" rests are only 2 feet 6 inches.

This plan of passing tubes through the boiler was suggested by Mr. Henry Booth, the Treasurer to the Railway Company, whose object was to expose the greatest surface to the action of the heated air with the least area of tube: by this means the heat is rapidly transmitted into the water, and prevents that escape into the chimney to which large pipes are more or less subjected.

The weight of the ***Rocket*** being 4¼ tons, the load, according to the conditions already cited, was 12¾ tons, making the total mass in motion 17 tons. The distance run at full speed was 12 miles, which was accomplished in 53′ 20″, being at the rate of 13½ miles an hour.

This being only a preparatory trial, no account was kept of the consumption of fuel, or of the other circumstances requiring consideration.

The *Novelty* of Messrs. Braithwaite and Ericsson was next exhibited. This Engine is so far novel as to carry the requisite quantity of water and fuel on the same carriage with the Engine. It consists of an upright boiler or steam reservoir, at the bottom of which is the fire-place, surrounded with water; the fuel is conveyed down a small tube which passes through this boiler, and combustion is supported by means of a blast worked by the Engine. From the bottom of this boiler another, of a cylindrical shape, passes horizontally above the main axles of the carriage, and a pipe, twice returned, passes through it for conveying the heated air from the furnace. The cylinders are placed perpendicularly with cross heads, working to two bell-cranks, which are connected by rods to the main axle of the carriage.

The appearance of the *Novelty* is very much in its favour: the machinery is ingeniously contrived to work out of sight, and the whole forms as compact a machine as can well be imagined.

The day being far advanced, and some dispute having arisen as to the method of assigning the proper load for the *Novelty*, no particular experiment was made, further than that the Engine traversed the course by way of exhibition, occasionally moving at the rate of 24 miles an hour.

The *Sans Pareil* of Mr. Hackworth was also exhibited. This Engine differs very little in its construction from those used on the Darlington Railway. The fire is contained in a tube which is continued along the inside of the boiler, and is returned back to the same end at which it entered. The cylinders, as in the ***Novelty***, are placed perpendicularly, and the pistons work from beneath to the connnecting rods which are attached to the outside of the two fore-wheels of the carriage. No particular experiment was made with the ***Sans Pareil*** on this day.

October 7th.—In consequence of the dispute above alluded to, the judges thought proper to draw up a new list of conditions, which was printed and circulated on the ground. The following is a copy:—

" The weight of the Locomotive Engine, with its full complement of water in the boiler, shall be ascertained at the Weighing Machine, by eight o'clock in the morning, and the load assigned to it shall be three times the weight thereof. The water in the boiler shall be cold, and there shall be no fuel in the fire-place. As much fuel shall be weighed, and as much water shall be measured and delivered into the Tender Carriage, as the owner of the Engine may consider sufficient for the supply of the Engine for a journey of thirty-five miles. The fire in the boiler shall then be lighted, and the quantity of fuel consumed for getting up the steam shall be determined, and the time noted.

" The Tender Carriage, with the fuel and water, shall be considered to be and taken as part of the load assigned to the Engine.

" Those Engines that carry their own fuel and water, shall be allowed a proportionate deduction from their load, according to the weight of the Engine.

" The Engine, with the Carriages attached to it, shall be run by hand up to the Starting Post, and as soon as the steam is got up to fifty pounds per square inch, the Engine shall set out upon its journey.

" The distance the Engine shall perform each trip shall be one mile and three-quarters each way, including one-eighth of a mile at each end for getting up the speed and for stopping the train; by this means the Engine, with its load, will travel one and a half mile each way at full speed.

"The Engine shall make ten trips, which will be equal to a journey of thirty-five miles, thirty miles whereof shall be performed at full speed, and the average rate of travelling shall not be less than ten miles per hour.

"As soon as the Engine has performed this task (which will be equal to the travelling from Liverpool to Manchester), there shall be a fresh supply of fuel and water delivered to her; and, as soon as she can be got ready to set out again, she shall go up to the Starting Post, and make ten trips more, which will be equal to the journey from Manchester back again to Liverpool.

"The time of performing every trip shall be accurately noted, as well as the time occupied in getting ready to set out on the second journey.

"Should the Engine not be enabled to take along with it sufficient fuel and water for the journey of ten trips, the time occupied in taking in a fresh supply of fuel and water shall be considered to be and taken as part of the time in performing the journey.

Liverpool, October 6, 1829."

Before the Judges arrived on the ground the *Novelty* had been got ready for the purpose of trying the load which the Judges had assigned to it yesterday, and, before the second trip was accomplished, the bellows for creating the blast gave way, and rendered the Engine incapable of going through its performance on this day.

A defect having been discovered in the boiler of the *Sans Pareil*, the Judges allowed Mr. Hackworth some further time to get it repaired.

To lessen the disappointment which these accidents occasioned to the numerous assemblage of anxious spectators, the *Rocket* was brought out, and a coach, capable of containing thirty persons, attached to it, which was moved at the rate of 24 to 30 miles an hour, to the great gratification of the several parties who had thronged during the day to enjoy so extraordinary a ride.

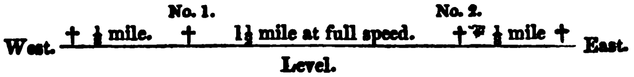
This evening the Judges ordered the *Rocket* to be in readiness at eight o'clock on the following morning, to go through its definitive trial according to the new conditions.

October 8*th*.—The *Rocket*, after having got a sufficient supply of water in the boiler, was weighed on the Machine, and found to be 4 tons 5 cwt. The load therefore was—

	Tons.	*Cwt.*	*Qrs.*	*Lbs.*
Engine..	4	5	0	0
Tender, &c..................................	3	4	0	2
Two Carriages loaded with Stones.....	9	10	3	26
Whole mass in motion..........	17	0	0	0

The time occupied in getting up the steam to 50 lbs. on the square inch was 57 minutes, and the fuel weighed out for the purpose was 142 lbs. of coke; but, since the "fire-box" was full of ignited coke when the steam was up, we cannot say how much was actually consumed in the process; neither do we consider this of much importance, because the quantity of steam generated will always be in proportion to the quantity of fuel consumed, and in instituting an inquiry into the comparative merits of Engines, a superiority in principle will show itself more readily when fully at work than in the mere operation of getting up the steam.

The length of the course was $1\frac{1}{2}$ mile, exclusive of $\frac{1}{8}$ of a mile at each end for stopping and getting up the speed of the Engine, train, &c. as shown by the following diagram:—



The number of trips for the first experiment was ten, making the distance travelled at full speed 30 miles, and the total distance 35 miles.

The following Table will show the time occupied in passing along the stage in each direction, and also the time lost in stopping and getting up the speed of the train at each end.

EXPERIMENT FIRST.

	Time of stopping and getting up the speed. WEST END.		Time going west from Post No. 2 to Post No. 1.		Time going east from Post No. 1 to Post No. 2.		Time of stopping and getting up the speed. EAST END.	
	Min.	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*
Started at	1	25	...	..	7	43	...	...
10° 36′ 50″	...	...	6	43	...	...	2	14
	3	42	...	...	7	08	...	...
	...	...	8	22	..	...	4	35
	2	28	...	...	7	52	...	...
	...	...	8	03	...	...	2	45
	2	55	...	...	6	07	...	...
	...	...	7	03	...	...	2	20
	2	27	...	...	6	31	...	...
	...	...	6	05	...	...	2	27
	2	05	...	..	5	55	...	...
	...	...	8	42	...	...	2	53
	4	05	...	...	5	55	...	...
	...	...	7	35	...	...	2	35
	2	24	...	...	5	40	...	...
	...	...	6	57	...	...	3	14
	3	25	...	...	5	18	...	...
	...	...	7	05	...	...	4	02
Ended at	2	15	...	...	4	12	...	...
1° 48′ 38″ ×	1	23	5	12	...	..	2	01
Whole time 3° 11′ 48″	28′ 34″ 29′ 06″		1° 11′ 47″		1° 2′ 21″ 1° 11′ 47″		29′ 06″	
Total stoppages......57′ 40″			Time when in motion.		2° 14′ 8″			

This part of the "ordeal" being completed, the Engine run down to the watering station and took a fresh supply of water; it then ran back to the starting post, and after having taken in some more fuel, it prepared for the second journey.

The time occupied was 14′ 34″.

EXPERIMENT SECOND.

	Time of stopping and getting up the speed. WEST END.		Time going west from Post No. 2 to Post No. 1.		Time going east from Post No. 1 to Post No. 2.		Time of stopping and getting up the speed. EAST END.	
	Min.	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*
Started at	1	38	...	...	6	15	...	...
2° 3′ 12″	...	...	7	32	...	...	2	08
	2	25	...	...	5	57	...	...
	...	...	7	20	...	...	2	23
	2	30	...	...	5	17	...	...
	...	...	6	12	...	...	2	59
	2	47	...	...	7	06	...	...
	...	...	6	47	...	...	3	40
	2	41	...	...	6	05	...	...
	...	...	6	33	...	...	2	11
	2	48	...	...	5	51	...	...
	...	...	7	18	..	...	2	32
	2	02	...	...	6	09	...	...
	...	...	7	46	...	...	2	29
	2	18	...	...	5	23	...	...
	...	...	8	19	...	...	3	38
	2	13	...	...	5	25	...	...
	...	...	6	32	...	...	2	06
Ended at	1	57	...	...	3	44	...	...
5° 0′ 21″ ×	0	45	5	18	...	...	2	10
Whole time	24′	04″	1° 9′	37″	57′	12″	26′	16″
2° 57′ 09″	26′	16″			1° 9′	37″		
Total stoppages ......50′ 20″			Time when in motion.		2° 6′	49″		

In the former of these experiments 30 miles were travelled in 2° 14′ 8″, which is at the rate of $13\frac{4}{10}$

miles per hour, and the time occupied at both ends of the stage, in stopping and getting up the speed of the train, was 57′ 40″, during which time the Engine travelled 5 miles.

In the latter experiment 30 miles were travelled in 2° 6′ 49″, which is at the rate of 14 2/10 miles per hour, and the stoppages at the ends amounted to 50′ 20″, during which time the Engine travelled 5 miles.

The quantity of fuel consumed in 70 miles was 1085 lbs. of coke, which, by taking the whole mass moved, viz. 17 tons conveyed over 70 miles, or 1190 tons over one mile, gives 0.91 lbs. per ton per mile; or, if we deduct the Engine and tender, and consider the available load only, it will be 1.63 lb. per ton per mile.

The quantity of water used in 70 miles was 580 imperial gallons.

In referring to the Tables, it will be found that the last trip of 3 miles, in each experiment, was made at the rate of 19¾ miles per hour; and the last eastward trip of 1½ mile was performed in 3′ 44″, which is upwards of 24 miles per hour. This fact shows that the Engine was working quite within its power, having in both experiments a reserve of steam for the last journey.

These experiments show that there is more friction in propelling the train than in drawing it, for it will be seen in the Table, that the time occupied in traversing the westward trip was almost invariably longer than in the contrary direction; and the waggons were propelled before the Engine in going westward, and drawn behind it in going eastward. If, in the last experiment we take the time for the eastward trips only, we shall have 57′ 12″ in running 15 miles, which is at the rate of 15¾ miles per hour; and since in practice the train may always be drawn after the Engine, the average rate of speed may be taken at 15¾ miles per hour.

Neither the *Novelty* nor the *Sans Pareil* being ready to enter upon their trials, the Judges deferred the further prosecution of the experiments until the 12th, so as to give the owners of these Engines an opportunity of getting every thing ready. Subsequently, however, to this arrangement, Messrs. Braithwaite and Ericsson requested that their Engine might be tried on Saturday the 10th, which the Judges very readily granted, and an advertisement appeared, stating that this Engine was to be tried on that day, and that it would perform more work than any Engine on the ground.

The 9th October then became a "dies non."

On the 10th October an unusual assemblage collected on the course to witness the exhibition of the *Novelty*, and this being Saturday, it was fully expected that the trials on this day would give some idea as to whom the premium would ultimately be awarded.

The *Novelty* was weighed, and after deducting the weight of the water and tank, was found to be 3 tons 1 cwt. As this Engine was constructed to carry its own water and fuel, the judges had some difficulty in assigning its proper load; however, after much discussion, they resolved on the following method:—

That since the *Rocket* weighed 85 cwt. and carried 191 cwt. of useful weight, then the *Novelty*, weighing 61 cwt. should, by a rule of three question, take 137 cwt. of useful weight, leaving each of the Engines to carry their fuel and water in their own particular way.

The weight of the whole train then was as follows:—

	Tons.	*Cwt.*	*Qrs.*	*Lbs.*
Engine, water tank, water, and fuel......	3	17	0	14
Two Carriages loaded with stones.......	6	17	0	0
Whole mass in motion..........	10	14	0	14

The time occupied in getting up the steam to 50 lbs. on the square inch was 54′ 40″, and the quantity of fuel weighed out for the purpose was 66 lbs. of coke and firewood; but for reasons before given, it was not ascertained how much remained in the furnace after the steam was up.

At eleven o'clock the *Novelty* commenced and passed the first post in good style, but in returning the pipe from the forcing pump burst, and put an end to the trial. The average rate of speed when in motion was upwards of 15 miles an hour, but since the distance was so short, it was impossible to form a correct estimate either of the powers of the Engine or of the consumption of fuel.

The pipe, however, was in the course of the day repaired, and the Engine made several trips with a coach (in which were many scientific gentlemen) at the rate of 24 to 28 miles per hour.

It was then agreed that the *Sans Pareil* should perform its task on Tuesday the 13th, and that the *Novelty* should be allowed another trial on Wednesday the 14th, these performances to conclude the contest.

TUESDAY, OCTOBER 13.

The *Sans Pareil* having been at work during the night, the water in the boiler was still hot, and consequently no notice was taken either of the time or the quantity of fuel required to raise the steam to 50 lbs. on the square inch. This part of the inquiry being of so little consequence, the Judges did not think it necessary to attend to it, particularly since much time would have been lost in ascertaining it.

The Engine, with its complement of water in the boiler, was then placed on the weighing machine, and found to be 4 tons 15½ cwt. One of the conditions issued by the Directors was, "that if any Engine be more than 4½ tons weight, it must be placed on six wheels;" and, since the *Sans Pareil* was not on six wheels, the Judges considered that it was not entitled to compete for the premium.

Mr. Hackworth contended that his Engine was not above weight, and that the weighing machine was not correct; however, it was at length thought advisable to let the Engine run on the same footing with the others, and see whether its merits entitled it to a more favourable consideration.

The weight of the whole train was as follows:—

	Tons.	*Cwt.*	*Qrs.*	*Lbs.*
Engine....................................	4	15	2	0
Tender, water, and fuel..................	3	6	3	0
Three waggons loaded with stone....	10	19	3	0
Whole mass in motion.......	19	2	0	0

The manner of performing this experiment was precisely similar to that with the *Rocket.*

	Time of stopping and getting up the speed. WEST END.		Time going west from Post No. 2 to Post No. 1.		Time going east from Post No. 1 to Post No. 2.		Time of stopping and getting up the speed. EAST END.	
	Min.	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*	*Min.*	*Sec.*
Started at	1	9	..	...	5	9	...	...
10° 10′ 21″	...	...	7	37	...	...	2	6
	2	12	...	..	6	3	...	...
	...	...	7	8	...	...	2	1
	2	11	...	...	6	8	...	...
	..	...	7	21	...	...	2	11
	2	35	...	...	5	34	...	...
	...	...	6	34	...	...	1	52
	2	35	...	...	3	59	...	...
	...	...	6	56	...	...	1	55
	2	40	...	...	6	1	...	...
	...	...	7	12	...	..	4	11
	2	54	...	...	6	22	...	...
	...	...	8	1	...	...	2	34
Ended at	3	31	...	...	5	31	...	...
12° 55′ 0″	...	..	...	..	...	...	3	18
	19′ 20′	47″ 08″	50′	49″	46′ 50′	27″ 49″	20′	08″
Total stoppages......	39′	55″	Time when in motion. }		1° 37′	16″		

In returning westward in the eighth trip the cold water pump got wrong, and from want of a supply of water in the boiler the leaden plug was melted, and the water and steam rushed into the chimney, and put an end to the experiment.

From the time of starting to the time of arriving at the post No. 2 in the eighth trip, a distance of $22\frac{1}{2}$ miles was ran in 1° 37′ 16″, which is at the rate of $13\frac{3}{4}$ miles per hour, and the time occupied in stoppages was 39′ 55″, during which time the Engine and train travelled $3\frac{7}{8}$ miles. The whole distance then is $26\frac{3}{8}$ miles, but since the Engine had got a considerable way in returning the eighth trip, the whole distance run to the time of stopping was $27\frac{1}{2}$ miles. The consumption of coke was 1269 lbs. in carrying $19\frac{1}{10}$ over the space of $27\frac{1}{2}$ miles, or $525\frac{1}{4}$ tons over 1 mile, and which gives $2\frac{4}{10}$ lbs. per ton per mile for the whole mass moved, or by deducting the weight of the Engine and tender gives $4\frac{1}{5}$ lbs. of coke per ton per mile nearly.

The quantity of water used in $27\frac{1}{2}$ miles was 274 Imperial gallons.

Before the Engine could be got ready again, it became too late to continue the experiments.

October 14*th*.—This being the day on which the premium was to be won, there was an unusual assemblage of visitors.

The *Novelty* was again brought out, and the usual preliminaries being gone through, it made a trip by way of rehearsal, to see if all its working parts were in good order. This being ascertained, the Engine was brought up to the starting post, and the same load being attached to it as on the 10th, it started on its journey.

The first trip of 3 miles was performed in 16′ 43″, which is at the rate of 10¾ miles an hour. In the second trip the pipe which conveys the heated air from the furnace through the horizontal boiler collapsed, and the steam, forcing its way into the fire place, was evolved from the bottom of the furnace into the atmosphere. This failure was at the time attributed to the yielding of a "green joint," and was considered as such by the Judges; but having seen the pipe when it was taken out, we feel convinced that its failure alone was sufficient to account for the accident, without the addition of any joint giving way.

The *Novelty* was then withdrawn, and Mr. Hackworth requested that he might be allowed another trial. The Judges refused, on the ground that his Engine was not only above weight, but that it was on such a construction as they could not recommend to the Directors of the Company.

The *Perseverance* of Mr. Burstall, which had met with an accident on its way to the course, had been got ready and brought out this day, but not being able to move at more than 5 or 6 miles per hour, Mr. Burstall declared that he had no intention of competing for the premium.

We believe also that Mr. Brandreth withdrew the *Cycloped.*

The course was thus left clear for the *Rocket*, which, after having gone through the "ordeal," and fulfilled every stipulated condition, was pronounced by all to be fully entitled to the prize; and to show that it had been working quite within its powers, Mr. Stephenson ordered it to be brought on the ground and detached from all incumbrance, and in making two trips it moved at the astonishing rate of 35 miles an hour.

These experiments have accomplished one very material object, and that is, getting rid of the smoke. Every Engine was constructed for using coke, and every one present must agree that in this respect they all fulfilled the conditions imposed, for there was not one particle of smoke to be perceived.

In considering the high velocities which each Engine attained with its load, we feel convinced that the loads assigned were too small. The conditions stipulated that each Engine should take three times its own weight at the rate of 10 miles an hour; but we find them moving from 14 to 19¾ miles, and in one instance at 24 miles an hour, with this load; and the subsequent trials with the *Rocket*, given in our "Observations, &c." page 26, have shown that even with a load of nearly eight times the weight of the Engines, a speed of 13 miles an hour was maintained. We name this, because when the weight of an Engine becomes one-fourth of the whole train, instead of one-ninth, the consumption of fuel, when estimated on the goods and waggons only, is very materially increased; for instance, in the "ordeal" which the *Rocket* passed through, 1190 tons gross weight were conveyed over 1 mile with 1085 lbs. of coke, which is equal to 0.91 of a lb. per ton per mile, or by estimating the goods and waggons only is 1.63 lb. per ton per mile; but if a gross load of 37¼ tons had been conveyed over the same distance, or 2607 tons over 1 mile, then the consumption of coke would be thus:—If 1190 tons require 1085 lbs., then 2607 will require 2377 lbs., which gives for the gross weight 0.91 of a lb. per ton per mile, as above, but considered on the available weight only is reduced from 1.63 lb. to 1.13 lb. per ton per mile, which is very nearly one-third less.

In corroboration of the truth of this method of reasoning, we will give the results of an investigation made with such a load as we consider to be about the average for economical purposes. The Engines with which the two following experiments were made are precisely similar in the principle of their construction, and differing only from the *Rocket* by having a greater number of tubes of a less diameter passing through the boiler.

EXPERIMENT FIRST.

A load of 34½ tons was conveyed over a space of 43½ miles, which is equal to 1500 tons conveyed over 1 mile, with a consumption of coke amounting to 1422 lbs., which is equal to 0.94 of a lb. per ton per mile, and if we add the weight of the Engine and Tender (7 tons) it will be equal to 1804 tons conveyed over 1 mile, and the consumption of coke will be 0.78 of a lb. per ton per mile.

The average speed when in motion was from 10 to 12 miles per hour.

EXPERIMENT SECOND.

A load of 28 tons was conveyed over a space of 36¼ miles, and a load of 32¼ tons over a space of 6 miles, which is equal to 1208 tons conveyed over 1 mile, with a consumption of coke amounting to 1008 lbs., which is equal to 0.83 of a lb. per ton per mile, or by adding the weight of the Engine and Tender, as in the former experiment, will be 0.67 of a lb. per ton per mile.

To these may be added an experiment which has been made with the *Novelty,* which, since the competition, has undergone considerable alteration. An additional cylinder, expressly for working the bellows, has been applied, and a more effectual communication made between the horizontal boiler and the steam reservoir. The pipe which conveys the heated air from the furnace has also been lowered, in order to prevent a recurrence of the accident which proved fatal to it during the trials for the premium. All these are decided improvements, and have enabled the Engine to work for a much longer time together than it was before capable of doing; at the same time they have added to its weight.

The distances and loads taken were as follows :—

	Tons.	*Cwt.*	*Qrs.*		*Tons.*	*Cwt.*	*Qrs.*	
3 miles with	7	9	2	equals	22	8	2	over one mile,
3 ditto „	17	6	3	ditto	52	0	1	ditto
28½ ditto „	28	1	0	ditto	799	8	2	ditto
3¼ ditto „	25	0	0	ditto	81	5	0	ditto
Total number of tons conveyed over one mile....................					955	2	1	

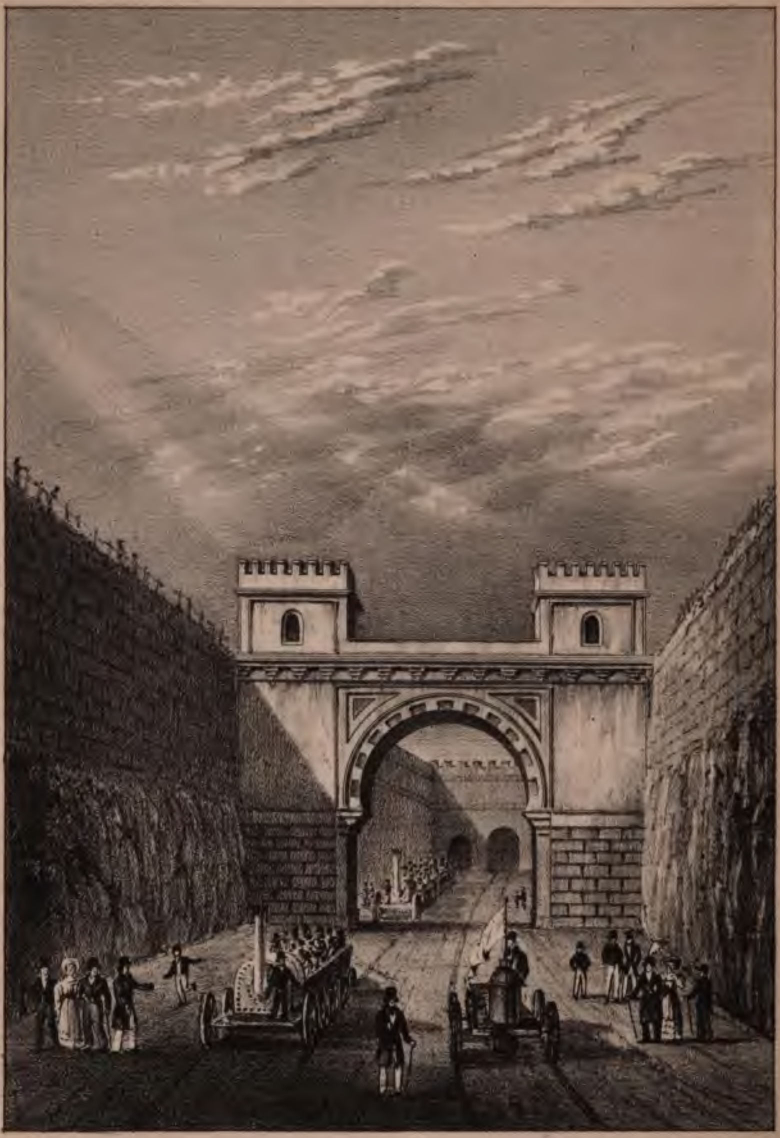
The consumption of fuel was 588 lbs. of coke, which is equal to 0.614 of a lb. per ton per mile—or, by adding the weight of the Engine as in the former cases (four tons), will be 0.53 of a lb. per ton per mile.

In comparing these experiments with those made in October, we find them much more favourable, both in regard to the consumption of fuel and in the loads conveyed. Indeed, we consider that the performances during the competition have not produced any result that can fairly be called superior to the daily performance of other Engines then in use. We admit that a greater speed was attained than had been contemplated, but the loads attached to each Engine were too small to show that their application would be attended with so much economy as more recent experiments have demonstrated. The Directors, in apportioning the loads, were no doubt influenced by the Report of Messrs. Walker and Rastrick, who fixed on 19½ tons of goods and waggons as a proper load for an Engine weighing 8 tons; and they also stated, that to increase the power of the Engine, that is, to enable it to take more than 19½ tons at 10 miles an hour, a corresponding increase to its weight must necessarily take place. The whole of the experiments have given so decided a negative to this statement, as to require no further comment.

Locomotive Engines, as well as Railways, may be said to be yet in their infancy, and but partially understood: when properly applied we believe they will be found highly advantageous; but we fear lest the opinion which has got too widely circulated, that Locomotives will ascend steep inclinations, may retard their introduction even where they are best fitted. We should be sorry to see their powers abused, for we doubt not but, when the Liverpool and Manchester Railway shall have been opened so as fully to develope the uses to which they may with safety be applied, that their introduction will become general throughout the kingdom.

Printed by Wales and Baines,
Castle-street.

BIBLIOTHECA · BODLEIANA ·



Printed by C. Hullmandel.

ENTRANCE TO THE LIVERPOOL STATION.

AN ACCOUNT

OF THE

LIVERPOOL AND MANCHESTER RAILWAY,

COMPRISING

A HISTORY OF THE PARLIAMENTARY PROCEEDINGS,

PREPARATORY TO THE PASSING OF THE ACT,

A DESCRIPTION OF THE RAILWAY,

IN AN EXCURSION FROM LIVERPOOL TO MANCHESTER,

AND A

POPULAR ILLUSTRATION OF THE MECHANICAL PRINCIPLES
APPLICABLE TO RAILWAYS.

ALSO, AN

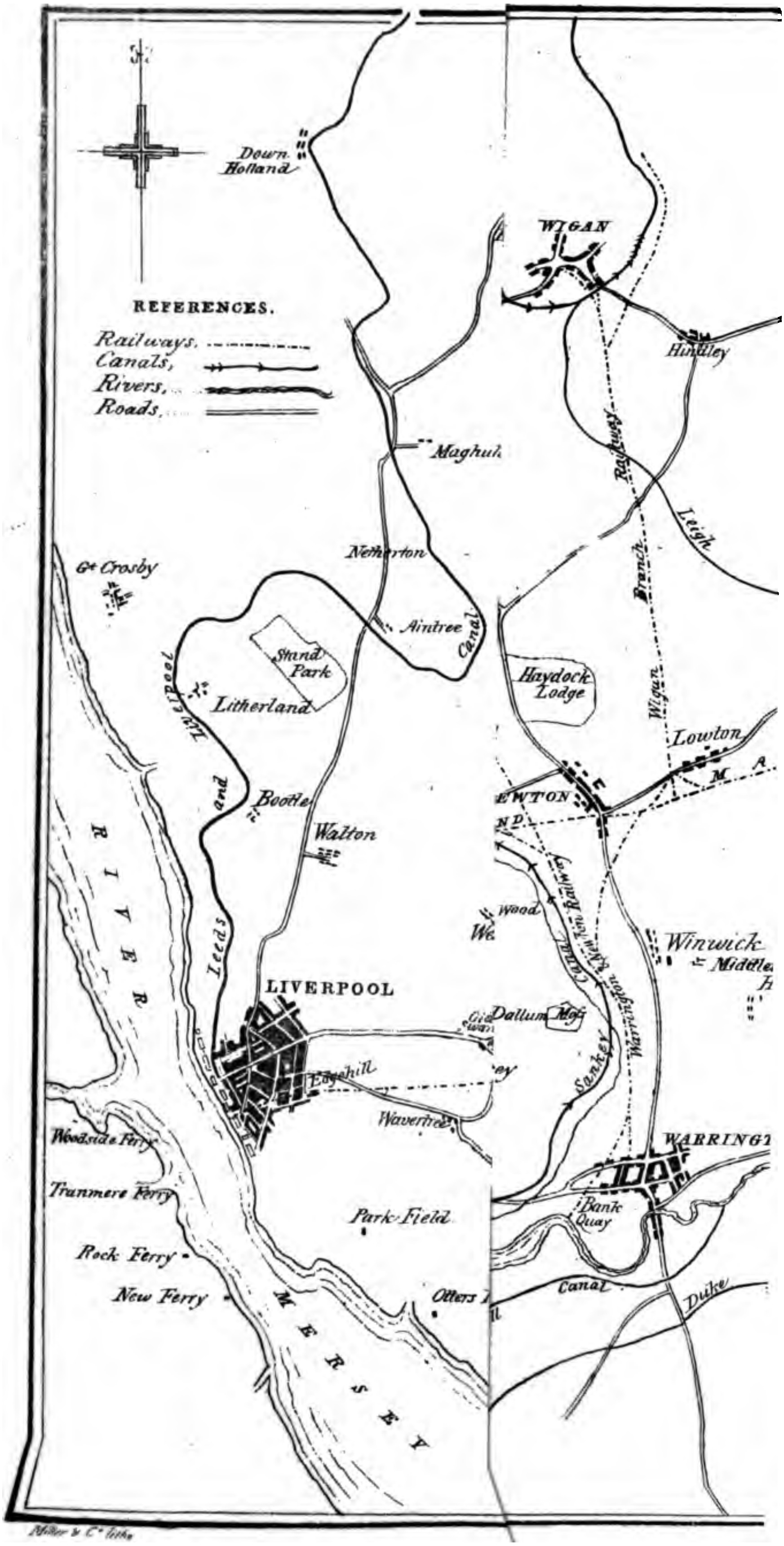
ABSTRACT OF THE EXPENDITURE FROM THE COMMENCEMENT
OF THE UNDERTAKING,

WITH OBSERVATIONS ON THE SAME.

BY HENRY BOOTH,
TREASURER TO THE COMPANY.

LIVERPOOL:
PRINTED BY WALES AND BAINES;
AND SOLD BY THEM AND THE BOOKSELLERS IN LIVERPOOL; BANCKS AND CO. MANCHESTER;
CADELL AND CO. EDINBURGH; AND HURST, CHANCE AND CO. LONDON.

BIBLIOTHECA



Miller & Cº litho

AN

ACCOUNT, &c.

CHAPTER I.

INTRODUCTION—PARLIAMENTARY PROCEEDINGS.

THE adoption of Railways as a means of inland communication, for the transit of merchandise and passengers, forms an era no less remarkable than the first introduction of Canals, and constitutes a change in the long-established modes of conveyance no less striking and important. The Railway, however, is by no means a recent invention: nearly two centuries have elapsed since the first partial introduction of Tram-roads, rudely constructed of wood, at a trifling outlay of capital and still smaller expenditure of scientific arrangement. The substitution of iron for wood was a great improvement; but the form of the rail continued for a long time very objectionable, consisting of flat pieces of cast-iron laid on the ground, with a side flange rising two or three inches to confine the wheel to its proper track. The rails thus resting on the ground, were unavoidably covered with soil or sand; and it was not till the adoption of the edge-rail, raised above the ground, that Railways attained those advantages over common roads which they are now acknowledged to possess.

In the last quarter of a century Railways have multiplied rapidly, especially in the neighbourhood of Newcastle and Sunderland; and a large amount of capital and skill have been employed in their construction, and in the erection and adaptation of the different kinds of machinery with which many of them are worked. Still these Railways are comparatively of small extent; detached, isolated and private undertakings, and appropriated exclusively to the conveyance of coals to the shipping wharfs on the Tyne and Wear.

The first public Railway, established by Act of Parliament for the conveyance of general merchandise and passengers, as well as coals, was the Stockton and Darlington. This Railway is about twenty-five miles in length, extending from the Witton Park Collieries, in the neighbourhood of West Houghton, in the county of Durham, to Stockton-upon-Tees, and passing within a few hundred yards of Darlington, which is situate about midway between the two extremities of the line. This Railway consists of a single road, with *sidings* every quarter of a mile, to allow carriages to pass one another. A small quantity of merchandise, and 300 or 400 passengers weekly, are conveyed along this line between Darlington and Stockton: but here, as in the neighbourhood of Newcastle, Coal is the staple commodity, the tolls on this article alone being six or seven times the amount derived from the aggregate of all the other sources of revenue. The subscribers to this undertaking had originally to encounter a long and strenuous opposition on the part of land-owners, whose property was affected, and of coal-proprietors, whose pecuniary interests were interfered with. The first application to Parliament was unsuccessful; but in 1823 the Act for the present line was obtained; and the 27th of September, 1825, has become memorable as the day on which the Stockton and Darlington Railway was opened to the public.

The project of the Liverpool and Manchester line was first discussed as early as 1822. Mr. William James, of London, Engineer, having witnessed the powers of the Locomotive Engine in the neighbourhood of Newcastle-on-Tyne, conceived that it might be successfully employed on a Railway for commercial purposes. He brought a letter of introduction to Mr. Sandars, a gentleman who, having had practical experience of the insufficiency of the existing modes of conveyance from Liverpool to Manchester, was prepared to give all due consideration to any plan which proposed a remedy for a tried grievance. Mr. Sandars adopted the scheme, and became father to the present undertaking. A preliminary survey was made of the country between the two towns, Mr.

Sandars being guarantee for the estimated cost. The line of road recommended in this survey was not ultimately adopted, but the project, after some intermission, went forward.

A combination of striking and favourable circumstances evidently belonged to a line of communication between the towns of Liverpool and Manchester: the one a commercial sea port, second in importance only to London; the other a large manufacturing town, and the centre and focus of a populous manufacturing district. Looking, indeed, at the intimate and necessary connection between the two places—foreign produce of every description passing daily from Liverpool to Manchester, and manufactured goods finding their way from Manchester to be shipped at Liverpool to every quarter of the globe; considering this incessant interchange of commodities, comprising at that period upwards of 1000 tons *per day* conveyed between the two towns, and this large traffic being rapidly on the increase—one should reasonably have expected to find the utmost facility of conveyance subsisting between the two towns, or at least that no very serious delays or difficulties would be found to impede the actual transit of commodities from the one place to the other. But how did the fact correspond with this reasonable expectation, and how far had the means of conveyance for goods and merchandise kept pace with the mighty commerce of the two towns?

The great canal proprietors, which for nearly a century had taken charge of the conveyance of merchandise between Liverpool and Manchester, are the

Mersey and Irwell Navigation (commonly styled the Old Quay) Company, and the Trustees of the Duke of Bridgewater's Canal. The flats or barges, in both cases, have to navigate the River Mersey from Liverpool to Runcorn, a distance of about twenty miles, according to the ordinary track which vessels are able to pursue, and thence by separate routes, the Duke of Bridgewater's navigation by canal terminating in Castle-field, Manchester, and that of the Old Quay Company consisting alternately of canals and the Rivers Mersey and Irwell, till it reaches the same great depot; the whole distance being about fifty miles. The Old Quay Company obtained their first Act of Parliament in 1733, and the Duke of Bridgewater in 1760. We shall take it for granted that, at this latter period, the trade of Liverpool had so far increased as to render expedient the establishment of a *second* means of conveyance, namely, the Bridgewater Canal. We have now, therefore, to ascertain whether, since the period of 1760, there has been such an increase in the trade and commerce of this district, as to render it probable that even a *third* line of communication might be desirable and beneficial to the public; and a few leading facts in the comparison will be abundantly sufficient to determine this point.

In 1760, the number of vessels which paid dock duties at Liverpool was 2560.

In 1824, when the Railway Company was formed, it was 10,000; the tonnage of the port having *more than doubled* in the ten preceding years, namely, since 1814.

In 1784, twenty years after the establishment of the *second* canal, an American vessel arrived in Liverpool, having on board for part of her cargo *eight bags of cotton*, which were seized by the officers of Customs, under the conviction that they could not be the growth of America!

In 1824, there were imported into Liverpool, *from America*, 409,670 bags of cotton.

In 1760, the population of Liverpool was about 26000.

In 1824, the population was 135,000.

The same stupendous increase is to be found in the trade and population of Manchester.

In 1760, the population was about 22,000.

In 1824, it was 150,000.

The first steam-engine used in Manchester was in the year 1790, thirty years after the *Act* was obtained for the *second* canal.

In 1824, upwards of 200 steam-engines were at work.

In 1824, there were nearly 30,000 power-looms employed, while only ten years previous there was *not one.*[*]

---

[*] Though the present argument required that I should show the great increase of trade up to 1824, it may not be amiss briefly to notice the augmentation of our commerce since that period.

In 1824, year ending 24th of June, the number of vessels paying dock dues in the port of Liverpool is stated above, at........................ 10,000

In 1829, it was.. 11,383

In 1824, year ending 31st of December, the cotton imported into Liverpool was .... 447,083 bags.

In 1829, the importation was.. 640,936 „

In 1824, the quantity of goods passing daily between Liverpool and Manchester was estimated at 1000 tons. It is now (1830) about 1300 tons per day; in the proportion of 1000 tons passing from Liverpool to Manchester, and 300 tons passing from Manchester to Liverpool.

But the trade which has increased with perhaps the greatest rapidity is the

It may be replied, however, to this statement, that admitting this vast increase in the population and commerce of the two towns, still, by increasing the number of boats, with facilities of loading and discharging, ample accommodation might be afforded to the public. But what are the facts as they existed in 1824? Mr. Sandars, in a pamphlet published in that year, expresses himself as follows:—" Notwithstanding all the accommodation the canals can offer, the delays are such that the spinners and dealers are frequently obliged to cart cotton on the public high road, a distance of 36 miles, for which they pay four times the price which would be charged by a Railroad, and they are three times as long in getting it to hand. The same observation applies to manufactured goods, which are sent by land carriage daily, and for which the rate paid is five times that which they would be subject to by the Rail-road. This enormous sacrifice is made for two reasons—sometimes because conveyance by water cannot be promptly obtained, but more frequently because speed and certainty as to delivery are of the first importance."—P. 17.

---

importation into Liverpool of live stock from Ireland, to be attributed mainly to the establishment of steam conveyance. The following is an authentic account of the import into Liverpool, principally from Ireland, for 30 months; and of this large supply no small portion it is calculated will seek a conveyance to Manchester and the neighbourhood by the Railway:—

	Large Cattle	*Calves.*	*Sheep.*	*Pigs.*
From June, 1827, to June, 1828.......	33,164	3,875	133,567	107,066
,, ,, 1828, to ,, 1829.......	49,674	6,786	125,197	155,319
,, ,, 1829, to Dec. 1829, six months ...	32,816	15,846	91,589	82,561
Total in 30 months, ending Dec. 1829.	115,654	26,507	350,353	344,946

About the same period also, the following Public Declaration was signed by upwards of 150 of the most respectable merchants of Liverpool:—

"We, the undersigned merchants and brokers resident in the port of Liverpool, do hereby declare that we have for a long time past experienced great difficulty in obtaining vessels to convey goods from this place to Manchester, and that the delay is highly prejudicial to the trading and manufacturing interest at large. That we consider the present establishments for the transport of goods quite inadequate, and that a new line of conveyance has become absolutely necessary to conduct the increasing trade of the country with speed, certainty and economy."—*(Sandars, p. 29.)*

Considering it, therefore, as undeniable that an increased facility of conveyance between the two towns was highly desirable, it became a question whether a *Railway* would best combine the essential requisites of safety, economy and despatch. In order the better to be enabled to form a judgment on this point, a deputation, consisting of Mr. Sandars, the late Mr. Lister Ellis, Mr. Kennedy, of Manchester, and the writer of this account proceeded to Darlington, where the Railway was then unfinished, and afterwards to the neighbourhood of Newcastle and Sunderland, where various Railways were in operation, and where both Locomotive and Fixed Engines were employed for the conveyance of coals from the pits to the respective places of shipment. This deputation made their Report to a Committee of Gentlemen in Liverpool, of which John Moss, Esq. was Chairman, on the 20th of May, 1824, when it was finally determined to form a Company of Proprietors for the establishment of a double Railway between Liverpool and Manchester. A subscription list was opened and speedily filled, principally with names connected with the towns of Liverpool and Manchester. A permanent Committee was afterwards appointed, of which Chas. Lawrence, Esq. at that time Mayor of Liverpool, was elected Chairman. Mr. Geo. Stephenson, of Newcastle-on-Tyne, was appointed Engineer. The necessary surveys were undertaken, and every preparation made for soliciting an Act of Incorporation in the ensuing Session of Parliament.

On the 29th of October, 1824, the Committee issued their Prospectus, which, as the first public announcement of the objects of the Company and the nature of the undertaking, I insert in this place:—

"LIVERPOOL & MANCHESTER RAIL-ROAD COMPANY.

COMMITTEE.

CHARLES LAWRENCE, Esq. *Chairman.*
LISTER ELLIS, Esq.
ROBERT GLADSTONE, Esq.
JOHN MOSS, Esq.
JOSEPH SANDARS, Esq.
} *Deputy Chairmen.*
ROBERT BENSON,
H. H. BIRLEY,
JOSEPH BIRLEY,
HENRY BOOTH,
THOMAS SHAW BRANDRETH,
JAMES CROPPER,
JOHN EWART,
PETER EWART,
WILLIAM GARNETT,
RICHARD HARRISON,
THOMAS HEADLAM,
ADAM HODGSON,
ISAAC HODGSON,
JOSEPH HORNBY,
JOHN KENNEDY,
WELLWOOD MAXWELL,
WILLIAM POTTER,
WILLIAM RATHBONE,
WILLIAM ROTHERAM,
JOHN RYLE,
THOMAS SHARPE,
JOHN WILSON, Esquires.

Parliamentary Agent, Thos. Moulden Sherwood, Esq.—*Engineer,* Geo. Stephenson, Esq.—*Solicitors,* Messrs. Pritt and Clay.—*Bankers,* Messrs. Moss, Rogers and Moss. Liverpool.

PROSPECTUS.

"The Committee of the Liverpool and Manchester Rail-road

Company think it right to state, concisely, the grounds upon which they rest their claims to public encouragement and support.

" The importance, to a commercial state, of a safe and cheap mode of transit, for merchandise, from one part of the country to another, will be readily acknowledged. This was the plea, upon the first introduction of canals: it was for the public advantage; and although the new mode of conveyance interfered with existing and inferior modes, and was opposed to the feelings and prejudices of landholders, the great principle of the public good prevailed, and experience has justified the decision.

" It is upon the same principle that Rail-roads are now proposed to be established; as a means of conveyance manifestly superior to existing modes: possessing, moreover, this recommendation in addition to what could have been claimed in favour of canals, namely, that the Rail-road scheme holds out to the public not only a cheaper, but far more expeditious conveyance than any yet established.

" The Liverpool and Manchester Rail-road is proposed to commence near the Prince's Dock, Liverpool, thence to Vauxhall-road, then through Bootle, Walton, Fazakerley, Croxteth, Kirby, Knowsley, Eccleston, Windle, Sutton, Haydock, Newton in Mackerfield, Golborn, Lowton, Leigh, Pennington, Astley, Irlam, Worsley, Eccles, Pendlebury, Salford, Hume, to the neighbourhood of the westerly end of Water-street, Manchester: in the whole, a distance of about thirty-three miles. By a reference to the plan it will be perceived that the road does not approach within about a mile and a half of the residence of the Earl of Sefton, and that it traverses the Earl of Derby's property over the barren mosses of Kirby and Knowsley, passing about two miles distance from the hall. In deciding upon the proposed route, the Committee have been anxious, at considerable inconvenience and expense, to select a line which may not only be eligible, considered in itself, but may be as little objectionable as possible, with reference to individual and local interests.

" The ground has been surveyed by eminent Engineers, and the estimated expense of a Rail-road, upon the most improved construction, including the charge for Locomotive Engines, to be employed on the line, and other contingencies, is £400,000,—which sum it is proposed to raise in 4000 shares of £100 each.

"The total quantity of merchandise passing between Liverpool and Manchester, is estimated, by the lowest computation, at one thousand tons per day. The bulk of this merchandise is transported either by the Duke of Bridgewater's Canal, or the "Mersey and Irwell Navigation." By both of these conveyances goods must pass up the river Mersey, a distance of 16 or 18 miles, subject to serious delays from contrary winds, and not unfrequently to actual loss or damage from tempestuous weather. The average length of passage, by these conveyances, including the customary detention on the wharfs, may be taken at 36 hours, longer or shorter, according to the favourable or unfavourable state of the winds and tides. The average charge upon merchandise, for the last fourteen years, has been about 15s. per ton.

"By the projected Rail-road, the transit of merchandise between Liverpool and Manchester will be effected in four or five hours, and the charge to the merchant will be reduced at least one-third. Here then will be accomplished an immense pecuniary saving to the public, over and above what is perhaps still more important, the *economy of time*. Nor must we estimate the value of this saving merely by its nominal amount, whether in money or in time: it will afford a stimulus to the productive industry of the country, it will give a new impulse to the powers of accumulation, the value and importance of which can be fully understood only by those who are aware how seriously commerce may be impeded by petty restrictions, and how commercial enterprise is encouraged and promoted by an adherence to principles of fair competition, and free trade.

"The Committee are aware that it will not immediately be understood by the public, how the Proprietors of a Rail-road, requiring an invested capital of £400,000, can afford to carry goods at so great a reduction upon the charge of the present water companies. But the problem is easily solved. It is not that the water companies have not been able to carry goods on more reasonable terms, but that, strong in the enjoyment of their monopoly, they have not thought proper to do so. Against the most arbitrary exactions the public have hitherto had no protection, and against the indefinite continuance or recurrence of the evil, they have but one security: IT IS COMPETITION THAT IS WANTED; and the proof of this assertion may be adduced from the fact, that shares in the Old Quay Navigation, of which the original cost was £70. have been sold as high as £1250. each!

"But it is not altogether on account of the exorbitant charges of the water carriers that a Rail-road is desirable. The present Canal establishments are inadequate to the great and indispensable object to be accomplished, namely, the regular and punctual conveyance of goods at all periods and seasons. In summer time there is frequently a deficiency of water, obliging boats to go only half loaded, and thus occasioning great inconvenience and delay; while in winter, they are sometimes locked up with frosts for weeks together, to the manifest hindrance of business. From these impediments a Rail-road would be altogether exempt. There is still another ground of objection to the present system of carriage by Canals, namely, the pilferage, an evil for which there is seldom adequate redress, and for which the privacy of so circuitous and dilatory a passage affords so many facilities. Whereas a conveyance by Railway, effected in a few hours, and where every delay must be accounted for, may be expected to possess much of the publicity and consequent safety of the King's highways.

"In addition to the transport of goods between Liverpool and Manchester, an important branch of revenue may be expected to result to the Proprietors of the projected road, from the conveyance of Coals from the rich mines in the vicinity of St. Helens; an advantage which the water companies do not possess, and which, from its importance and extent, may probably enable the Proprietors to reduce their rates of carriage still lower than now contemplated. These coals at present pass along the Sankey Canal and down the Mersey to Liverpool, a distance of about 30 miles. By the Railway, the distance will be shortened one-half, and the charge for transit very materially reduced.

"Amongst the widely diffused benefits to be expected from the proposed Rail-road must especially be enumerated, no inconsiderable advancement in the commercial prosperity of Ireland. The latent energies of that country, her capabilities as a manufacturing power, will be developed by being brought into easy contact and communication with the manufacturing districts of this kingdom: while every article of her agricultural industry will experience an increased demand from the cheapness and facility with which it will be introduced into the populous counties of Lancaster and York. Whatever shortens the time of conveyance practically diminishes the distance, and whatever is saved in the cost of carriage is a gain to Ireland.

" In the present state of trade and of commercial enterprise, despatch is no less essential than economy. Merchandise is frequently brought across the Atlantic from New York to Liverpool in twenty-one days; while, owing to the various causes of delay above enumerated, goods have in some instances been longer on their passage from Liverpool to Manchester. But this reproach must not be perpetual. The advancement in mechanical science renders it unnecessary: the good sense of the community makes it impossible. Let it not, however, be imagined, that were England to be tardy, other countries would pause, in the march of improvement. Application has been made, on behalf of the Emperor of Russia, for models of the Locomotive Engine: and other of the continental governments have been duly apprized of the important schemes for the facilitating of inland traffic, now under discussion by the British public. In the United States of America also, they are fully alive to the important results to be anticipated from the introduction of Rail-roads; a gentleman from the United States having recently arrived in Liverpool, with whom it is a principal object to collect the necessary information in order to the establishment of a Railway, to connect the great rivers Potomac and Ohio.

" The immediate and prominent advantages to be anticipated from the proposed Rail-road, are increased facilities to the general operations of commerce, arising out of that punctuality and despatch which will attend the transit of merchandise between Liverpool and Manchester, as well as an immense pecuniary saving to the trading community. But the inhabitants at large of these populous towns, will reap their full share of direct and immediate benefit. Coals will be brought to market in greater plenty, and at a reduced price; and farming produce, of various kinds, will find its way from greater distances, and at more reasonable rates. To the landholders, also, in the vicinity of the line, the Rail-road offers important advantages in extensive markets for their mineral and agricultural produce, as well as in a facility of obtaining lime and manure at a cheap rate in return. Moreover, as a cheap and expeditious means of conveyance for travellers, the Railway holds out the fair prospect of a public accommodation, the magnitude and importance of which cannot be immediately ascertained.

"The Committee do not think it necessary to dwell upon probable and contingent sources of revenue to the Proprietors, and of benefit to the community: but it is impossible entirely to overlook the tendency of increased economy and despatch to extend the commercial intercourse, not only upon the immediate line of road, but diverging in ramifications to the north and the south, and especially towards the rich and populous town of Bolton; a short branch line being sufficient to bring that extensive manufacturing district into rapid and direct communication with this port.

"Such is a brief view of the scheme in which the Liverpool and Manchester Rail-road Company have embarked, and which, while it promises such manifold advantages to the public, the Committee feel confident will afford a fair and liberal return for the capital invested by the Proprietors.

"CHARLES LAWRENCE, *Chairman*.

"*Liverpool*, 29*th October*, 1824."

Such, then, was the scheme of the Liverpool and Manchester Railway, requiring, however, the sanction of the legislature before it could be carried into effect. Parliament met early in the ensuing year, and a portion of the Railway Committee attended in London, in the first week of Feb. 1825, to watch the progress of the Bill through the House of Commons—an undertaking by no means a sinecure, as those who have had the good or ill fortune to be concerned in carrying forward contested bills will readily admit. The Committee anticipated a strenuous opposition, and they were not disappointed. The Proprietors of three Canals (the Duke of Bridgewater's, the Mersey and Irwell, and the Leeds and Liverpool,) each in itself no despicable opponent, forgetting their mutual jealousy and former disagreements, appeared in formidable array, acting on one impulse for the common safety, and prepared at all hazards to put down so intolerable an innovation on established modes and vested rights. This was to be expected. But the opposition did not end here. Two noble Lords, the Earls of Derby and Sefton, a part of whose estates the Railway crossed, made common cause with the Canals to prevent the establishment of a Railway. On the part of these noblemen, it was contended that the sanctity of their domains would be invaded, and the privacy of their residences destroyed, by thus bringing into their neighbourhood a public highway, with all the varied traffic of coals and merchandise and passengers, that would be the consequence of such an establishment.

The question being fairly brought before the House of Commons, the proceedings were briefly as follow:—On the 8th of Feb. 1825, the petition for the Bill was presented to the House of Commons, and on the 9th the Committee on Standing Orders resolved that the "orders" had been complied with. On the 18th of Feb. the Bill was read a first time in the House of Commons. On the 2d of March the Bill was read a second time, after a debate of about an hour and a half, on which occasion Sir John Newport, Mr. Huskisson, Mr. W. Peel, Mr. Doherty, Mr. Calcraft, and Mr. Brougham, spoke in favour of the measure—

Mr. Green, Member for Lancaster, and Mr. George Philips against it. The second reading was carried without a division. In the Committee on the Bill, General Gascoyne was requested to act as Chairman, an office which he kindly undertook, and which he fulfilled with infinite patience and perseverance during a protracted contest of nearly three months. On the 21st of March (all preliminary forms having been complied with), Mr. Counsellor Adam, on behalf of the Railway Company, made his opening speech in Committee, and on the following days evidence was heard in favour of the Bill, or in Parliamentary language, in proof of the preamble—the general tenor of the evidence being in confirmation of the statements and arguments put forth in the Company's Prospectus. Mr. Adam was supported by Mr. Sergeant Spankie, Mr. Joy, and Mr. Wm. Brougham. On the 2d of May, Mr. Spankie summed up for the Railway, and on the 3d Mr. Counsellor Harrison led on the hostile van, supported by Mr. Alderson, Mr. Parke, Mr. M'Donald, Mr. Earle, and Mr. Cullen. He did not deny that great inconvenience and delays had arisen from the defective system of Water conveyance, nor that occasionally it took as long a time to transport merchandise from Liverpool to Manchester as it did to bring it from America to Liverpool; nor that a direct line of 30 miles on a Railway would present a speedier conveyance than a circuitous route of near 50 miles through Canals and tide-way. But it was contended that the Canals and River were capacious enough for all the traffic of the port; that, moveover, our levels and sections were erroneous; that the Locomotive Engine was an unsightly object; and that the formation of the Railway would cost three or four times as much as the estimate: nay, Mr. Francis Giles, Civil Engineer, was produced to record his opinion that it would cost upwards of £200,000. to carry the Railway across Chat Moss alone:—from all which it followed, that, from considerations of kindness to the Proprietors of so wild and impracticable a scheme, the Bill ought to be rejected by the legislature.*

On the subject of the levels and sections, the opponents of the Bill were correct in their animadversions: a considerable error had been committed by the Surveyors for the Railway; which, when discovered, was acknowledged in Committee. The rectifying of this error was to the advantage of the Railway Company, inasmuch as the cost of the corrected line would have been less than that of the erroneous section. The impression on the Committee, however, was unfavourable; and some degree of doubt and uncertainty was necessarily thrown on the whole of the surveying department.

---

* I subjoin an abstract from Mr. Giles's evidence before the Committee of the House of Commons, on the 5th May, 1825, taken from an official copy:—

Q. Be so good as to tell us whether in your judgment a Rail-road of this description can be safely made over Chat Moss, without going to the bottom of the Moss?

A. I say certainly not.

Q. Will it be necessary, therefore, in making a Rail-road which is to stand, to take out, along the whole line of the road, the whole of the Moss to the bottom?

A. Undoubtedly.

Q. Will that make it necessary to cut down the 33 or 34 feet of which you have been speaking?

A. Yes.

Q. And afterwards to fill it up with other soil?

A. To such a height as the Rail-road is to be carried; other soil mixed with a portion of the Moss.

Q. But suppose they were to work upon this stuff, could they get their carriages to the place?

A. No carriage can stand on the Moss short of the bottom.

Q. What would they do to make it stand—laying planks, or something of that sort?

A. Nothing would support it.

Q. So that, if you could carry a Rail-road on this fluid stuff—if you could do it—it would still take a great number of men, and a great sum of money. Could it be done, in your opinion, for £6000.?

A. I should say £200,000. would not get through it.

Q. My Learned Friend wishes to know what it would cost to lay it with diamonds? &c. &c.

On the 30th of May, Mr. Harrison concluded the case for the opponents of the Bill.

On the 31st, Mr. Adam replied; after which, the Committee divided on the preamble, which was *carried* by a majority of *one*, 37 members being in favour of the Bill, and 36 against it.

Such a result, after a three months' Parliamentary campaign, and after 37 working days spent laboriously in Committee, was far from encouraging to the promoters of the Bill. All the clauses and detail of the Bill had still to be discussed, scrutinized, and opposed; and it was hardly to be expected, after so protracted an opposition, that Members of Parliament, without that strong personal and pecuniary interest, in defence of which the Canal Proprietors might be supposed to make every effort, would still persevere in what, to many at least, might now be considered a hopeless contest. Accordingly, on the 1st of June, the first clause of the Bill, empowering the Company to make the Railway, was lost, on a division, by a majority of 19 to 13. The clause to take land was then put to the vote and also lost; whereupon Mr. Adam, on behalf of the Railway Company, withdrew the Bill.

Such was the result of the first attempt in Parliament to obtain the sanction of the legislature to the formation of the Liverpool and Manchester Railway. Scarcely, however, was the fate of the Bill decided for the passing Session before the first movement was made, and the first steps taken, for a renewed effort in the succeeding year. In the course of Parliamentary proceedings it has been observed, that where a Bill is vehemently opposed, whether with a view to the public good or from the impulse of private interests, still the measure is seldom carried the first year. The ground is broken; the arguments on both sides are stated, and probably exaggerated; the heat of parties is displayed, and in some measure exhausts itself. In another Session the subject is more likely to be discussed with calmness and temper; and if some public benefit be included in the scheme proposed, the chances of success are much increased in the second year.

The promoters of the Railway felt confident that their failure was not to be attributed to any lack of public opinion in favour of the great work in which they had engaged; and understanding that many Members of Parliament were strongly impressed with the importance of the measure in question, considered as a national undertaking, it was thought desirable that a meeting should take place between the Railway Committee and such of the Parliamentary supporters of the Bill as could conveniently attend, to record some expression of opinion on the then posture of affairs, and especially with reference to proceedings in future. Accordingly, the following Members of Parliament met the Railway Committee (by invitation) on the 4th of June, 1825, at the Royal Hotel, St. James'-street, viz.;—

General Gascoyne.
The Lord Viscount Forbes.
Sir Philip Musgrove.
Sir Robert Wilson.
Right Hon. W. Huskisson.
Right Hon. W. Bagwell.
The Hon. General King.
The Hon. Col. Lowther.
Thomas Spring Rice, Esq.
W. Y. Peel, Esq.
William Holmes, Esq.
Marcus Beresford, Esq.
Richard Hart Davies, Esq.
W. H. Trant, Esq.
Robert Price, Esq.
General Hart.
Colonel Cawthorne.
Colonel Crosbie.
Alderman Bridges.
Robert Downie, Esq.
N. Sneyd, Esq.

General Gascoyne was called to the chair, and after some desultory conversation,

Mr. Huskisson said, that he perceived nothing connected with the discussions on this Bill in the Committee of the House of Commons, or in the rejection of the measure, after the preamble of the Bill was proved, which should deter the subscribers from renewing their application to Parliament another Session. Looking at the immense traffic between Liverpool and Manchester—taking into consideration the well-being of Ireland, which required the utmost facilities of introducing her produce into the great manufacturing districts—he had no hesitation in saying that, in his opinion, some additional and improved means of conveyance between Liverpool and Manchester would be highly desirable. It was, therefore, that he considered the measure now under discussion of great public importance; and whatever temporary opposition it might meet with, he conceived that Parliament must ultimately give its sanction to the undertaking.

Sir Robert Wilson expressed a wish that, as regarded the opponents of the measure, every discussion and proceeding might be carried on in the spirit of conciliation.

Mr. Spring Rice said, he could state that almost all the commercial bodies in Ireland were favourable to the measure; and he thought Hon. Members would render a great service to that country by supporting the Bill when again brought forward. He considered the Railway would be particularly important in facilitating the intercourse between Manchester and those districts in Ireland which were already engaged in certain processes of the cotton manufacture.

Mr. Holmes read a letter from Lord Lowther, regretting his inability to attend; also a favourable opinion of *Mr. M'Adam*, on the facility of carrying roads over bogs and mosses; a question which had occasioned much discussion in the Committee of the House.

After some further conversation, *Mr. Lawrence*, as Chairman of the Railway Deputation, having expressed his conviction that the subscribers would be disposed to renew their application to Parliament in the next Session, the following resolution, moved by ***Mr. Huskisson***, and seconded by ***Mr. W. Peel***, was unanimously adopted :—

"That it is the opinion of this meeting, that for the purpose of insuring increased facility, cheapness, and despatch in the very extensive intercourse in merchandise and manufactured goods between the towns of Liverpool and Manchester, and also in the general trade between this great manufacturing district and Ireland, it is expedient to provide additional and improved means of conveyance between Liverpool and Manchester."

The second resolution was proposed by ***Mr. Spring Rice*** and seconded by ***Mr. Bagwell***,

"That the failure of the Liverpool and Manchester Railway Bill during the present Session, in consequence of the rejecting of two enacting clauses, after the preamble of the Bill had been proved, does not appear to this meeting an event which ought to discourage the subscribers from renewing their application the next Session of Parliament, should it appear to the subscribers advisable to carry this important measure."

After this resolution was agreed to, the meeting broke up; and thus terminated the proceedings of the Railway Committee, in connection with their application to Parliament in the Session of 1825.

The interval was short between the labours of this Session and the preliminary steps requisite to be taken preparatory to the ensuing Parliamentary campaign, The Committee of the Railway, on the return of their Deputation from London, advertised their intention of adopting "measures for a renewed application to Parliament the ensuing Session:" and on the 1st of July, it was resolved that Mr. John Rennie be requested to undertake the office of Engineer to the Company. After some correspondence, it was agreed that Messrs. George and John Rennie should be the Engineers of the Railway; and Mr. George Rennie, pursuant to instructions, undertook a new survey of the country between Liverpool and Manchester, in order "to report to the Committee the best line for a Railway."

On the 12th of August, the Committee, on the recommendation of the Engineers, determined to adopt a new line of way, passing considerably to the south of the former route. In furtherance of this resolution, Mr. Charles Vignoles, on behalf of Messrs. Rennie, was appointed to prepare the necessary sections and plans of the projected undertaking. As these advanced towards completion, it became evident that the cost of the new line would much exceed the former estimate of £400,000. It became a question, therefore, with the Committee, in what way to raise such additional sum as might be requisite.

In an early stage of the undertaking it was proposed to R. H. Bradshaw, Esq. M. P. as Trustee for the Proprietors of the Duke of Bridgewater's Canal, to become a shareholder in the Railway. It appeared reasonable that the Proprietors of the Canal Navigations, whose property might be considerably affected by the establishment of a new mode of conveyance, should have the option of taking part in the projected scheme. Mr. Bradshaw, however, declined the proposition. If it be inquired why the same offer was not made to the other great Navigation Company (the Mersey and Irwell), the answer is obvious. The Duke of Bridgewater's Canal is private, entailed, and indisposable property; whereas a Proprietor of the Mersey and Irwell Company had the power, any moment, to reduce his interest in the Water conveyance, and take a share in the Railway, if he so thought fit.

The Committee of the Railway, at the present juncture, determined to renew the overture which they had formerly made, but not through the intervention of Mr. Bradshaw. A communication was opened more directly with the Marquis of Stafford, the party beneficially interested in the Duke's Canal, through the medium of James Loch, Esq. M.P. his Lordship's confidential adviser. The proposal was met in the spirit in which it was made; and, after the discussion of various preliminary points, it was agreed that the Marquis should become a subscriber to the new line of Railway, to the extent of 1000 shares. This arrangement being completed, the Committee lost no time in issuing their second Prospectus, in which the circumstance is made known to the Proprietors and to the public. The following is a copy:—

" LIVERPOOL & MANCHESTER RAILWAY COMPANY.

NEW LINE.

COMMITTEE.

CHARLES LAWRENCE, Esq. *Chairman.*
ROBERT GLADSTONE, Esq. } *Deputy Chairmen.*
JOHN MOSS, Esq. } *Deputy Chairmen.*
JOSEPH SANDARS, Esq. } *Deputy Chairmen.*
ROBERT BENSON, Esq. Liverpool.
H. H. BIRLEY, Esq. Manchester.
JOSEPH BIRLEY, Esq. Ditto.
BEN. BOOTH, Esq. Ditto.
HENRY BOOTH, Esq. Liverpool.
THOMAS S. BRANDRETH, Esq. Ditto.
JOHN EWART, Esq. Ditto.
PETER EWART, Esq. Manchester.
R. H. GREGG, Esq. Ditto.
R. HARRISON, Esq. Liverpool.
THOS. HEADLAM, Esq. Liverpool.
ADAM HODGSON, Esq. Ditto.
ISAAC HODGSON, Esq. Ditto.
JOSEPH HORNBY, Esq. Ditto.
JOHN KENNEDY, Esq. Manchester.
AARON LEES, Esq. Ditto.
W. MAXWELL, Esq. Liverpool.
WILLIAM POTTER, Esq. Ditto.
WILLIAM RATHBONE, Esq. Ditto.
WILLIAM ROTHERAM, Esq. Ditto.
JOHN RYLE, Esq. Manchester.
THOMAS SHARPE, Esq. Ditto.
JOHN WILSON, Esq. Liverpool.

Parliamentary Agent, **THOMAS M. SHERWOOD, Esq.—*Engineers,* Messrs. GEORGE and JOHN RENNIE.— *Solicitors,* Messrs. PRITT and CLAY.—*Bankers,* Messrs. MOSS, ROGERS and MOSS, Liverpool.**

CAPITAL……………………£510,000.

PROSPECTUS.

" The Committee of the Liverpool and Manchester Railway, before entering upon the labours which a renewed application to Parliament will impose upon them, are desirous to advert to the causes which led to the unsuccessful termination of their late efforts; and, at the same time, briefly to explain the grounds upon which they rest their anticipations of success in the ensuing Session.

" A very prominent objection, taken by the opponents of the Bill, was founded on the errors in the section and levels, as exhibited before Parliament. These errors the Committee at once acknowledged and regretted; and, to avoid all chance of similar complaint in future, they have engaged the professional services of most eminent Engineers, aided by assistants of undoubted talents and activity, whose combined efforts justify the fullest assurance, not only of the correctness of the plans and sections, but that the whole line will be laid down and arranged with that skill and conformity with the rules of mechanical science, which will equally challenge approbation, whether considered as a national undertaking of great public utility, or as a magnificent specimen of art.

" A second objection to the measure (which, however, was insisted upon out of doors more than in Parliament) was the interruption and inconvenience anticipated from the line of road crossing various streets in Liverpool and Manchester. This difficulty has been completely obviated. In the new line, recommended by Messrs. Rennie, the Railway enters Liverpool by means of a tunnel and inclined plane, thus effecting a direct and most desirable communication with the King and Queen's Docks, without interfering with a single street. It does not enter the town of Manchester at all, the line terminating near the New Bailey Prison, in the township of Salford.

"A third objection to the measure was taken by the Old Quay Company, on the ground that the Railway interfered with their navigation, by reason of a bridge in the neighbourhood of Manchester, over the River Irwell. The Committee are happy to state that this difficulty is avoided, inasmuch as the new line does not cross the Irwell at all.

"A fourth manifestation of opposition was on the part of the Leeds and Liverpool Canal Company, on the ground that the Railway passed *under* their Canal, in its way to the Prince's Dock. However futile such an objection, it is satisfactory to be enabled to state, that even this assumed ground of opposition is altogether avoided, as the line does not go near the Canal in question.

"Another and more plausible objection was founded on the employment of the Locomotive Engine. It was contended, in the *first* place, that this new and peculiar power was incompetent to perform the task assigned to it; in the *second* place, that it was unsafe; and *lastly*, that in its operation it would prove a public nuisance. By the evidence, however, it was proved that it was perfectly competent to perform all that was proposed to be accomplished; and, before the evidence was closed, the Counsel for the opponents of the Bill admitted that it was *safe*. Upon the third point of objection, the Committee are confident such improvements will be made in the construction and application of this effective machine, as will obviate all objection on the score of nuisance; and, as a guarantee of their good faith towards the public, they will not require any clause empowering them to use it,—or they will submit to such restrictions in the employment of it as Parliament may impose, for the satisfaction and ample protection both of proprietors on the line of road and of the public at large.

" The last, but not the least important objection which the Railway had to encounter, was on the part of several land-owners on the line. Amongst their opponents, on this ground, the Committee regret they were obliged to number the noble Earls of Derby and Sefton, whose estates the Railway crossed for a considerable distance, as well as others, whose property the line unavoidably intersected.

" The Committee most fully admit that the opinions and personal convenience of proprietors on the line of road are entitled to every consideration, and they have been most anxious, by all practicable means, to meet the wishes or to remove the objections of every land-owner on the road. They are happy to be able to state, that they can no longer, in this respect, find an opponent in Lord Sefton, as they do not, in the line of road they are about to apply for, cross any portion of his Lordship's estate. And with reference to the Earl of Derby, they conceive they are entitled to apply the same observation, inasmuch as the new line crosses only a few detached fields of his Lordship's property, far removed from the Knowsley domain, and the great turnpike road from Liverpool to Manchester intervening.

" With reference to the land-owners generally upon the new line, the Committee have to state, that they have spared no pains to accommodate the exact route to the wishes of proprietors whose estates they cross; whether, on the one hand, by removing the road to a distance from the mansions of proprietors, and from those portions of estates more particularly appropriated to game preserves, or, on the other hand, by introducing it more immediately into the vicinity of districts abounding with coal, which, by this means, will be brought into a cheap and expeditious communication with the Liverpool and Manchester markets. And they are happy to state, that their efforts in these respects have been in a great measure successful. In an important national undertaking, where a road has to be carried through a populous country for thirty miles, it will hardly be expected that every proprietor will assent, or that no individual will consider himself aggrieved. The Committee have used every effort to render the measure not only unobjectionable, but advantageous to every land-owner on the line. In all cases they are prepared to give a full value for the land they may require; and, should there be instances where unavoidable inconvenience is occasioned, they are most anxious to admit, that peculiar damage must be met by peculiar compensation.

"In regard to the existing means of conveyance, the Committee are desirous to state, that they are actuated by no hostile feeling to their interest and prosperity. They have felt that the increased and increasing trade of the two great towns of Manchester and Liverpool, and the rapidly increasing intercourse with Ireland, demanded additional facilities in the means of transit; and the professed and sincere desire of the Committee has been confined to supply this want. The Committee have the satisfaction of being able to state, that, in accordance with this feeling, the opposition of the most powerful of the existing establishments has been removed, by the Marquis of Stafford having, for himself and those of his family who are beneficially interested in the profits of the Duke of Bridgewater's Canal, become a subscriber to the Railway to the extent of One Thousand Shares. Being satisfied that the proceedings of last Session of Parliament have removed the misapprehensions which existed, both in regard to the nature and the management of the Bridgewater Canal, they felt it would be unfit to continue their opposition to the proposed measure in its improved form.

"Having thus disposed of the objections and difficulties which the Committee have had to encounter, they will briefly advert to those prominent and unequivocal advantages of the measure upon which they rest their claim to the favour of the public, and the sanction of Parliament.

"In their prospectus of last year, the Committee stated 'the total quantity of merchandise passing between Liverpool and Manchester at *one thousand tons per day.*' This quantity, it would seem, is underrated, the whole traffic being admitted, on all hands, in Committee of the House of Commons, to be 1200 tons per diem; which immense aggregate tonnage is, at present, subject to all the delays incidental to the river navigation.

"The Committee of the Railway propose to effect the transit of merchandise in a few hours, with uniform regularity, and at such reduced rates as will secure to the towns of Liverpool and Manchester a pecuniary saving, which, whether estimated in proportion to the expenditure upon which it is effected, or with reference to the aggregate amount, has seldom been equalled in any scheme of improvement submitted to the public.

"Neither is the immediate pecuniary saving to the towns of Liverpool and Manchester to be estimated with reference merely to the cost of conveying merchandise between the respective towns. The *travelling* between Liverpool and Manchester is upon the most extensive scale; and the economy to be effected in this branch of expenditure, though impossible to be estimated with accuracy, must be considered as most important, and, of itself, no small recommendation of the undertaking.

"The advantages, however, above enumerated are only a part of the beneficial results which this scheme proposes. The line of Railway, as now laid down, passes through a rich and extensive coal district, in full working, for the supply of Liverpool, and requiring only a facility of transport to be brought into requisition for the supply of Manchester. At a moderate computation, Liverpool requires for its local consumption 900 tons of coal per day, besides what is required for foreign commerce, and for the numerous steam-packets which sail daily through the season between Liverpool and various ports in Ireland, Scotland, and Wales. An aggregate consumption of 500,000 tons per annum may be taken as under the mark. Of this large quantity, a considerable proportion is brought to market by land carriage; extensive fields of coal in the direct line of the Railway having no other means of access to Liverpool. With reference to Manchester, the ordinary consumption for domestic purposes may be considered the same as in Liverpool, and the quantity used in the extensive factories of that town may be computed as equivalent to the demand for the steam vessels, and for the export trade at Liverpool: the aggregate consumption, therefore, of the two towns may be estimated, with sufficient accuracy, at ONE MILLION of tons per annum.

"The importance to the community of a moderate price to be paid for an article of such extensive and universal consumption is immediately apparent; and some idea of the benefit to be derived from such a facility of transport as may ensure a more enlarged and effectual competition may be formed from the circumstance, that in Manchester the price of coals was advanced 1s. 6d. per ton immediately upon the Railway Bill being withdrawn in the last Session of

Parliament; while in Liverpool, within the last thirty-five years, the price of the best coal has been advanced upwards of 7s. per ton, that is, nearly 100 per cent. But, estimating the reduction in the price of this article at 2s. per ton, here is a saving of £100,000. per annum (an amount equal to the whole assessed taxes of the two towns) effected upon a single article, not of luxury, and confined to the higher or mercantile classes of the community, but an article of the first necessity, of daily and hourly consumption, and forming no small item in the expenditure of every poor man's family.

" Moreover, it would be to take a very narrow and imperfect view of the great question now under discussion, to limit our consideration to the immediate accommodation of the mercantile classes, to the pecuniary saving proposed to the travelling community, or even to the still more important saving to the consumers of coals, and of every description of goods conveyed between Liverpool and Manchester. The question demands a wider survey and the consideration of more distant results. We must contemplate the important effects upon the commerce of the nation, which are to be anticipated, on the one hand, from *affording*, or, on the other hand, from *denying* facilities to the commercial operations of this great county. Above all, we must look to Ireland, the natural granary of the manufacturing districts of this country. To the sister kingdom a facility of intercourse and conveyance between Liverpool and the interior of Lancashire and Yorkshire is of paramount importance; in the first place, for the cheap and regular transport of her agricultural produce; and secondly, for the rapid transit of cotton and woollen goods in different stages of their manufacture, which alone seems wanting to foster the growing industry of Ireland; to give to her some proportionate advantage for her cheap labour, and thus render her an auxiliary and an helpmate to the more stable manufacturing establishments of this country.

" But the subject does not end here. It becomes a question of serious import whether this country, which is indebted for so much of her wealth, and power, and greatness, to the bold and judicious application of mechanical science, shall now pause in the career of improvement, while it is notorious that other nations will adopt the means of aggrandisement which we reject,—whether England shall relinquish the high vantage ground she at present possesses, not more with a reference to the direct operations of commerce and manufactures, than, generally, in the successful application of the most important principles of science and of art.

"The Committee feel that it is unnecessary to dwell at greater length on the question they have thus brought before the public. They are about to apply for the sanction of the legislature; and they are determined to relax no efforts on their part to bring about the honourable and speedy accomplishment of the great work in which they have engaged.

"CHARLES LAWRENCE, *Chairman.*

"*Liverpool, December* 26, 1825."

The time was now arrived when the question was again to be brought under the consideration of the legislature. A Deputation from the Railway Committee accordingly assembled in London in the first week in February, 1826.

On the 7th of February, the *Petition* for the Bill was presented to the House of Commons by General Gascoyne.

On the 9th, the compliance with the standing orders was proved in Committee.

On the 10th, the Bill was read a *first time* in the House of Commons.

On the 20th, it was read a *second time,* without discussion.

On March 6, Mr. Counsellor Adam made his opening speech in Committee, and on the same side were Mr. Sergeant Spankie, Mr. Joy, and Mr. W. Brougham.

After the estimates and other evidence in the Engineering department had been recorded, the general evidence in favour of the Bill, and with reference to the trade and commerce of the two towns, occupied two days.

On the 9th of March, Mr. Spankie summed up, and Mr. Counsellor Earle opened his case on behalf of the opponents. The injury to be apprehended to certain land-owners on the line of Railway, and the competency of the Canal Companies to carry on the trade between Liverpool and Manchester, were the topics principally enforced.

On the 15th of March, Mr. Harrison, for the Canals, summed up, in a speech of two hours, the burden of which was, that the Railway, as a conveyance, would be neither cheap nor expeditious; that it would be a grievous injury to the land-owners on the line, and at the same time ruinous to the projectors themselves.

On the 16th of March, Mr. Adam *replied;* after which the room was cleared, and on the division, the Preamble of the Bill was voted to be *proved,* by a majority of 43 to 18.

On the 6th of April, the Bill was read a third time in the House of Commons. The debate on this occasion was spirited; General Gascoyne moved the third reading, seconded by Mr. W. Peel; the Hon. Edward Stanley moved that the Bill be read that day six months, and was seconded by Sir Isaac Coffin. Mr. Huskisson and Sir John Newport spoke in favour of the Bill; and Mr. Philips (now Sir Geo. Philips) and Capt. I. Bradshaw against it. On the division, the numbers were 88 in favour, 41 against—majority 47.

On the 7th of April, the Bill was read a first time in the House of Lords.

On the 10th of April, Lord Dacre moved the second reading, when the Earl of Derby declared his intention to oppose the Bill in Committee, though he should not object to the second reading.

On the 13th of April, Mr. Adam opened the case for the Railway in the Committee of the Lords, thirty-three Peers being present, Lord Kenyon having consented to take the chair.

The evidence, on both sides, was similar in effect to that offered to the House of Commons. On the subject of the Locomotive Engine, however—a machine which had been represented to the House of Commons in so formidable a light,—evidence was brought forward by the opponents of the Bill; but so poor a case was made, and so little objectionable did the Engine appear to be, even from the testimony of the opponents, that the Lords did not think it necessary to hear any evidence on the other side, although it was tendered by the Counsel for the Bill.

On the 20th of April, Mr. Sergeant Spankie summed up, on behalf of the Railway, and Mr. Alderson opened in opposition.

On the 27th of April, Mr. Harrison summed up for the opponents, and Mr. Adam replied; after which, the Committee adjourned till the 1st of May.

On that day the Committee of the Lords re-assembled, thirty-two Peers being present. On a division, the preamble was declared to be proved, the numbers being 30 in favour—2 against.

Amongst the Peers in favour of the Bill were Lord Kenyon, the Earl of Lonsdale, the Bishop of Bath and Wells, the Bishop of Chester (now Bishop of London), the Marquis of Salisbury, Earl of Cassillis, Lord Dacre, Earl of Caernarvon, &c. &c.

The Earl of Derby and the Earl of Wilton were the opposing parties. The Bill was then read a third time in the Lords, and passed without a division.

Such is a brief outline of the Parliamentary proceedings on the Liverpool and Manchester Railway Bill; a measure which called into activity very powerful and conflicting interests. It could not, indeed, be expected that wealthy and long-established Companies, exercising their joint monopolies by prescriptive right and undisputed usage, could contemplate with the liberality of advocates for FREE TRADE the establishment of a Company great and powerful as themselves, for the avowed purpose of carrying on, by land, that mighty traffic and interchange of commodities between Liverpool and Manchester, which had been so long and so profitably carried on by water. To put down, in limine, a scheme so startling in its character, and withal so full of unknown consequences, was an object worthy of a strenuous and combined effort. The attempt was accordingly made: no labour was spared, no expedient left untried, no expenditure withheld. The greatness of the effort, however, on the one side, called forth proportionate exertion on the other. The aggregate pecuniary cost entailed on the parties concerned in the contest, was not less than from sixty to seventy thousand pounds: it has been estimated much higher. But the contest is over, and the result will be satisfactory to all who contemplate with pleasure the commercial prosperity of the country, or who take an interest in marking those great steps in the progress of mechanical science, the successful study and varied application of which, to arts and manufactures, have contributed in no small degree to raise this country to its present pre-eminence in wealth, power, and civilization.

CHAPTER II.

FORMATION OF THE RAILWAY AND EXPENDITURE.

THE first General Meeting of Subscribers, under the authority of the Act, was held in Liverpool on the 29th of May, 1826, when twelve Directors were chosen by the Proprietors, in conjunction with three Directors nominated by the Marquis of Stafford, to carry into effect the formation of the projected Railway. The first meeting of *Directors* was on the following day, when Charles Lawrence, Esq. was elected Chairman, and John Moss, Esq. Deputy Chairman; and the Board immediately took into consideration the choice of a Principal Engineer. It was obvious, that in an undertaking of such magnitude, a *resident* Engineer of experience and ability was indispensable; and the Directors naturally turned their attention to Mr. Stephenson, of Newcastle, a gentleman thoroughly acquainted with practical mechanics, and possessing more experience in the construction and working of Railways than perhaps any other individual. The Directors, at the same time, wrote to Messrs. Geo. and John Rennie, requesting them to undertake the professional superintendence of the undertaking On the 17th of June, Mr. Geo. Rennie had an interview with the Directors, on which occasion the subject was discussed ; and, in conclusion, Mr. Rennie proposed to the Directors to superintend the execution of the work, making six visits per annum, and remaining on the ground seven or ten days at each visit, but stipulating, at the same time, that the *resident* Engineer should be of his own appointing. On the 19th of June, the Directors took Mr. Rennie's proposition into consideration. They would have been glad of the professional assistance of Mr. Rennie, but it was their duty to take advantage of the best practical knowledge within their reach. The trust reposed in them, and the responsibility attaching to its due fulfilment, were too weighty to allow of their being much influenced by ordinary punctilios. Their course was direct to the great object they had in view. Mr. Rennie's proposition was respectfully declined, and Mr. George Stephenson was elected Principal Engineer to the Company.

The first point of actual operation was on Chat Moss, where the draining was commenced in June, 1826. The first shaft of the Liverpool Tunnel was opened in September of the same year, but very little progress was made in either of these departments of the work during 1826; and the earth-work (comprising the cuttings and embankings along the whole line) was not commenced till January, 1827. It will not be surprising that some delay should take place in the first instance, before a sufficient quantity of waggons, implements, and materials could be constructed or collected, to enable the Engineer to make much progress in the execution of the work. In Mechanics, it is found that it is not easy to put great weights *speedily* into rapid movement; and a variety of impediments must generally be encountered at the commencement of great undertakings. In the case of the Railway, the purchase of land was a preliminary step, requiring time and consideration to accomplish. Early in 1827, however, the machine was fairly in motion; the necessary arrangements were made; assistant Engineers were appointed; and operations in various parts of the line were in progress.

One of the objects of the Directors, in the summer of 1826, had been to make arrangements to obtain a loan of £100,000. from the Exchequer Loan Commissioners, appointed by the authority of Parliament to aid the completion of public works by the loan of money, under proper securities for its repayment by instalments, in a series of years. On a correspondence with the Commissioners, it was considered necessary to have the authority of a special Act of Parliament for the purpose; and accordingly, a General Meeting of Proprietors, on the 11th of December, 1826, empowered the Directors of the Railway to apply to Parliament for an Act to authorise the loan in question. The Act was obtained in the spring of 1827, and in June of the same year £100,000. was received from the Commissioners. With the aid of this loan, in addition to the several calls on the Subscribers, the Directors were enabled to push forward the work with more than ordinary vigour, and consequently to give employment to an increased number of labourers, which, at the period in question, and under the circumstances of the time, was an object of no small importance.

During the whole of the year 1827, the formation of the Tunnel under Liverpool was carried forward with spirit and perseverance. Night and day the excavation proceeded, and many difficulties in the execution of the work had to be overcome. In some places the substance excavated was a soft blue shale, with abundance of water; in other places a wet sand presented itself, requiring no slight labour and contrivance to support till the masonry which was to form the roof was erected. In passing under Crown-street, near the Botanic Garden, for want of sufficient props the superincumbent mass fell in from the surface, being a depth of 30 feet, of loose moss-earth and sand.* On some occasions the miners refused to work, and it not unfrequently required the personal superintendence and encouragement of the Engineer to keep them at their posts. Nor is this surprising, considering the nature of the operation: boring their way almost in the dark, with the water streaming around them, and uncertain whether the props and stays would bear the pressure from above till the arch-work should be completed. Those who visit the Tunnel in its present state, illuminated with gas-lights, and traversed by horses, carriages, and crowds of passengers, will not easily picture to themselves the original dark and dangerous cavern, with the roof and sides supported by shores, while the miners pursued their arduous task by the light of a few candles, whose feeble glimmer glancing on the water which ran down the sides, or which spread out in a sheet below, was barely sufficient to show the dreariness of the place. But while some portions of the Tunnel were excavated under circumstances of no little difficulty and danger, and requiring all the skill and energy of the Engineer to accomplish, other portions were hewn through a fine red sand-stone, clean, dry, and substantial, and requiring neither props nor artificial arching; the natural rock forming the roof of the excavation.

---

* This happened while the Engineer was absent from Liverpool.

The Tunnel was constructed in seven or eight separate lengths, communicating with the surface by upright shafts, through which the substance excavated was conveyed away. The exact joinings of these different lengths, so as to form one complete whole, as now exhibited, was, of course, from time to time an object of considerable interest, and to the Directors of some anxiety; and the accuracy with which this was effected is highly creditable to the Engineer, and to Mr. Locke, the Assistant Engineer for that department.

Nearly two-thirds of the Tunnel were completed in 1827, at an expense of twenty thousand pounds; and about the same money was expended in the cuttings and embankings along the line. The total expenditure of the Company on the 31st of December, 1827, including the cost of obtaining the Act of Parliament, and other preliminary disbursements, was £212,855. 19s. 8d.

Early in the year 1828, it became evident, notwithstanding this large expenditure, that the progress of the works was not advancing with that celerity which was to be desired. On the earth-work, the estimate of which amounted to £138,000., only £20,000. had been expended at the close of 1827. The Directors became fully sensible of the importance of expediting the whole work. The interest on the capital expended, and the loss of all income till the Railway, or at least a considerable portion of it should be completed, afforded motive sufficient to induce the Company to push forward the operations with still increasing speed.

In the spring of this year (1828) the Directors obtained an Act of Parliament for altering the line of road, improving the curves, and shortening the distance, by avoiding several circuitous routes, as laid down in the Parliamentary plan. The improved parts of the road are comprised between certain lands in the township of Sutton, near Rainhill, and that part of the line situate in Culcheth, near Bury-lane.

On the 9th of June, 1828, it was reported to the Directors that the last joining between the several lengths of the Tunnel was effected, and at that time all very serious difficulties in the execution of this branch of the undertaking were surmounted. In this year principally, was effected the *piling* for the foundations of the piers of the great Viaduct over the Sankey valley, a business of much labour and cost, but indispensable for the security of the superstructure. About two hundred piles, varying from 20 to 30 feet in length, were driven hard into the foundation site of each of the ten piers. The heavy ram employed to impart the finishing strokes, hoisted up with double purchase and snail's pace to the summit of the Piling Engine, and then falling down like a thunderbolt on the head of the devoted timber, driving it perhaps a single half inch into the stratum below, is well calculated to put to the test the virtue of patience, while it illustrates the old adage of—"slow and sure." The Viaduct comprises nine arches of 50 feet span each, stretching across the valley of the Sankey, over which the Railway was to be carried, at a height of nearly 70 feet above the level of the Sankey Canal. During the present year (1828), was completed the Company's bridge over the turnpike road and the old Mill Dam at Newton, and the operations on Chat Moss were carried on without intermission, embanking at each end, and draining, levelling, &c. on the centre portions.

On the 31*st of December*, 1828, the total expenditure was £461,899. 19s. 6d., which included the following items:—

On account of	Chat Moss	£17,503	7	3
,,	Cuttings & Embankings	84,565	19	3
,,	Tunnel	33,937	14	2
,,	Sankey Viaduct...........	32,223	6	9
,,	Land	101,962	9	11
,,	Iron Rails, Chairs, &c.	63,010	3	10

Early in the year 1829, the Directors, with the sanction of the Proprietors, applied to Parliament and obtained their fourth *Act*, the purport of which was—first, to improve the termination of the line at the Manchester end, by carrying the Railway in a more direct course over the Irwell into Manchester, instead of allowing it to terminate near the New Bailey, in Salford, as set out in the original plan. This alteration was a great improvement, as it brought the Railway to a station in Water-street, in the centre of the great Carrying Companies' Establishments; affording, at the same time, convenient access to the different parts of Manchester, whether with a view to merchandise laden in the Railway waggons, or passengers arriving in the Railway coaches.

Another important object of the Act of the present year was to authorise the Company to raise an additional capital of £127,500. by 5100 £25. *shares*, each holder of an original £100. *share* being entitled to one £25. *share*. The purpose of this new fund was to enable the Company to provide depots, machinery, waggons, carriages, &c. with all appurtenances belonging to a *Carrying Department;* for it is to be observed, that the original Railway Act requires the Company to be carriers, though it does not provide the means of carrying. That the raising of this additional capital was deemed expedient by the Proprietors at large, may be inferred from the circumstance that only fifteen of the new shares (out of 5100) were declined by the parties entitled to them, under the Act.

In the spring of 1829, the Directors were still anxious for increased despatch in the execution of the work, and the Engineer, in consequence, was instructed to order the Contractors at the principal cuttings throughout the line, to employ two sets of labourers, and to work by night as well as day. The operations accordingly proceeded still more rapidly than heretofore, though it must be allowed at considerably increased expense; and had it not been for an extraordinary wet summer and autumn, the earth-work for a complete line of communication between Liverpool and Manchester might have been accomplished by the end of 1829, or the beginning of 1830, and the Railway laid down for operations within a few months from that period. As it was, very considerable delay was occasioned by the heavy and long-continued rains, besides no triflingexpense to the Company, in pumping the water from the deep cuttings, which were too apt to assume the appearance of a Canal rather than a Railway.

The principal structure completed in 1829, was the Company's bridge to carry the Liverpool and Warrington turnpike road over the Railway at Rainhill. The line of the public road at this place, crosses the Railway in an oblique direction, at an angle of 34 degrees, the span of the arch being 54 feet, while the breadth of the Railway under the bridge is only 30 feet. It is called a Skew Bridge, in popular phraseology, and is a very fine specimen of this kind of building, every stone of the arch being shaped with angles and curve adapted to the position in which it is placed. The Winton bridge, *over* the public road, near Eccles, is a very neat specimen of the same style of arch, but without the massive grandeur of the bridge at Rainhill.

In the present year, one road-way was laid along the whole extent of Chat Moss, and the Rocket Steam Engine, with a carriage and company, passed over it on the first day of 1830. The practicability of carrying the Railway over this Moss was seriously questioned in the House of Commons, and was honestly doubted by numbers who were acquainted with the soft and pulpy state of this huge bog—in some places 30 to 35 feet deep—and so fluid, that an iron rod would sink through the Moss by its own gravity. The Railway, indeed, for the most part, floats on the surface, its compactness and buoyancy in the most fluid places being assisted by hurdles of brushwood and heather, laid under the wood sleepers which support the rails. The portion of the Moss which presented the most difficulty in its completion was about half a mile on the east border, where an embankment of about 20 feet had to be formed above the natural level. The weight of this embankment resting on a semi-fluid base, pressed down the original surface: many thousand cubic yards gradually and silently disappeared, before the line of road made any approach to the proposed level. By degrees, however, the whole mass beneath and on each side of this embankment became consolidated by the superincumbent and lateral pressure, and a little perseverance finally completed the work.

In September, 1829, was commenced the Company's bridge over the Irwell, in the improved line of road authorised by the Act of that year. This was the last great structure on the line of Railway from Liverpool to Manchester.

In the appendix will be found a general abstract of the total expenditure of the Railway, showing the cost of the different branches of the undertaking. This document may not be without interest to those who shall hereafter embark in similar adventures; though it will be evident that no very exact rule of comparison can be laid down, whereby to estimate the cost of different Railways; for not only have the wages of labour and the expense of materials to be taken into the account, but especially, the time and circumstances under which the work has to be accomplished—whether, notwithstanding unfavourable seasons, considerations of the earlier opening of the road, and more speedy acquisition of a profitable income, may still justify the prosecution of the work with unabated vigour—by night as well as by day—even at the increased expense which will thereby unavoidably be incurred. The Liverpool and Manchester Railway is a magnificent work; but it will be useful to keep in mind that such works cannot be executed except at an expenditure of no ordinary magnitude. This Railway will cost above £800,000., including the charge for stations and depots at each end, and machinery, engines, waggons, &c. for a carrying department. The immense traffic between Liverpool and Manchester amply justifies this outlay. But with reference to any similar scheme, in extension of the Railway system, it is desirable the projectors should impartially calculate the cost of the work, as well as the income it may be expected to produce; and especially that they should make an ample allowance beyond the first estimate of the expenditure, before they embark in the undertaking.

CHAPTER III.

DESCRIPTION OF THE RAILWAY—EXCURSION FROM LIVERPOOL TO MANCHESTER.

THERE is so little in scenery that is interesting on the turnpike road from Liverpool to Manchester, that a formal description of the way between the two towns may appear to be rather an unpromising undertaking. The traveller along the Railway, however, will speedily admit that there is little similitude between the two routes; the whole character, structure, and appearance of the Railway being altogether different from the general aspect of the turnpike road. Instead of a uniform, flat, and uninteresting country, the line of Railway is diversified continually by hill and dale, offered to the contemplation of the traveller in a sort of inverse presentment; the passenger by this new line of route having to traverse the deepest recesses, where the natural surface of the ground is the *highest*, and being mounted on the loftiest ridges and highest embankments, riding above the tops of the trees, and overlooking the surrounding country, where the natural surface of the ground is the *lowest*,—this peculiarity and this variety being occasioned by that essential requisite in a well-constructed Railway—a level line—imposing the necessity of cutting through the high lands and embanking across the low; thus, in effect, presenting to the traveller all the variety of mountain and ravine in pleasing succession, whilst in reality he is moving almost on a level plane, and while the natural face of the country scarcely exhibits even those slight undulations which are necessary to relieve it from tameness and insipidity.

To accomplish a complete survey of the Railway, we should commence our journey of observation at the Liverpool end, in the Company's yard, in Wapping. Here the lower entrance of the great Tunnel is accessible through an open cutting, 22 feet deep and 46 feet wide, being space for four lines of Railway, with pillars between the lines to support the beams and flooring of the Company's warehouses, which are thrown across this excavation, and under which the waggons pass to be loaded or discharged through hatchways or trap doors communicating with the stores above; waggons loaded with coal or lime passing underneath the warehouses to the open wharfs at the Wapping end of the station.

Proceeding along the Tunnel, the line of Railway curves to the right, or south-east, till it reaches the bottom of the inclined plane, which is a perfectly straight line, 1980 yards in length, with a uniform rise of three-quarters of an inch to a yard. The Railway from Wapping to the commencement of the inclined plane is level; the whole rise, therefore, from Wapping to the Tunnel mouth, at Edge-hill, is 123 feet. The Tunnel is 22 feet wide and 16 feet high, the sides being perpendicular for five feet in height, surmounted by a semicircular arch of 11 feet radius: the total length is 2250 yards. It is cut through various strata of red rock, blue shale and clay, but principally through rock of every degree of hardness, from the softest sand-stone to the most compact free-stone, which the axe or the chisel will with difficulty penetrate. It frequently was found necessary, in the progress of the work, to make an artificial vault of masonry, which has been effected by brick arch-work in those places where the natural rock could not be trusted to support the superincumbent mass. The height from the roof of the Tunnel upwards to the open surface of the ground, varies from 5 feet to 70, the greatest mass of superstratum being in the vicinity of Hope-street and Crabtree-lane. The whole length of this vast cavern is now furnished with gas-lights, and the sides and roof are *whitewashed,* to give better effect to the illumination. The different colours and peculiar appearance of the varying strata through which the Tunnel passes are thus hidden from view, and the attention is no longer attracted to those faults or slips in the solid rock, which indicate that the whole mass has been rent asunder by one or more of those terrible convulsions of nature, of which the traces are so frequently visible, but of which no other record remains. The geologist will be disappointed, in traversing this subterranean vault, to find the natural varieties converted by lime-water into one uniform and artificial appearance; but the principle of utility is paramount in a commercial undertaking.

At the upper or eastern end of the Tunnel, the traveller emerges into a spacious and noble area, 40 feet below the surface of the ground, cut out of the solid rock, and surmounted on every side by walls and battlements. From this area there returns a small Tunnel, 290 yards in length, 15 feet wide, and 12 feet high, parallel with the large one, but inclining upwards in the opposite direction, and terminating in the Company's premises in Crown-street, at the upper and eastern boundary of Liverpool; being the principal station for the Railway coaches, and the depot for coals for the supply of the higher districts of the town.

Proceeding eastward from the two Tunnels, the road passes through a Moorish archway, at present unfinished, which is to connect the two Engine-houses, and will form the grand entrance to the Liverpool stations. This structure is from a spirited design of Mr. Foster's, a representation of which I have placed as a suitable Frontispiece to this account of the Railway. The traveller now finds himself on the open road to Manchester, and has an opportunity of contemplating the peculiar features of a well-constructed Railway, the line in this place being perfectly level; the slight curve, which was unavoidable, beautifully set out; the road-way clean, dry, and free from obstructions; and the rails firmly fixed on massive blocks of stone. Crossing Wavertree-lane, the Railway descends for 5½ miles at the rate of four feet in the mile,—a declivity so slight and uniform as not to be perceived by the eye, but still sufficient to give a mechanical advantage and facility of motion to a load passing in that direction. The road a little beyond Wavertree-lane is carried through a deep marle cutting, under several massive stone archways, thrown across the excavation to form the requisite communications between the roads and farms on the opposite sides of the Railway. Beyond the marle cutting is the great rock excavation through Olive Mount, about half a mile to the north of the village of Wavertree. Here the traveller passes through a deep and narrow ravine, 70 feet below the surface of the ground, little more space being opened out than sufficient for two trains of carriages to pass each other; and the road winding gently round towards the south-east, the prospect is bounded by the perpendicular rock on either side, with the blue vault above, relieved at intervals by a bridge high over head, connecting the opposite precipices. The sides of the rock exhibit already the green surface of vegetation, and present altogether far more of the picturesque in their appearance than might be expected from so recent an excavation. At night, when the natural gloom of the place is further deepened, the scene from the bridges above will readily be imagined to be novel and striking. The light of the moon illuminating about half the depth, and casting a darker shade on the area below—the general silence interrupted at intervals by a noise like distant thunder—presently a train of carriages, led on by an Engine of fire and steam, with her lamps like two furnaces, throwing their light onward in dazzling signal of their approach—with the strength and speed of a war-horse the Engine moves forward with its glorious cavalcade of merchandise from all countries and passengers of all nations. But the spectacle is transient as striking; in a moment the pageant is gone—the meteor is passed; the flaring of the lamps is only seen in the distance, and the observer, looking down from the battlement above, perceives that all again is still and dark and solitary.

Emerging from the Olive Mount cutting, you approach the great Roby embankment, formed of the materials dug out of the excavation we have described. This embankment stretches across the valley for about two miles, varying in height from 15 to 45 feet, and in breadth at the base from 60 to 135 feet. Here the traveller finds himself affected by sensations the very reverse of what he felt a few minutes before. Mounted above the tops of the trees, he looks around him over a wide expanse of country, in the full enjoyment of the fresh breeze, from whatever quarter it may blow.

This vast embankment strikingly exhibits how much may be accomplished when our efforts are concentrated on one grand object. There is a feeling of satisfaction by no means common-place, in thus overcoming obstacles and surmounting difficulties, in making the high places low and the rough places plain, and advancing in one straight and direct course to the end in view; while the pleasure afforded by the contemplation of this great work is further enhanced, when considered in contrast with ordinary and every-day impressions.

After passing the Roby embankment you cross the Huyton turnpike road, leaving Huyton Church and village on the left hand, and proceed in a slightly curved direction to the bottom of the inclined plane at Whiston, between seven and eight miles from the

Company's station in Liverpool. This plane rises in the ratio of three-eighths of an inch in a yard, (or 1 in 96.) It is a mile and a half long in one straight line, and the inclination (being so slight) would scarcely attract observation, did not a decrease in the speed of the carriages indicate that an important change had taken place in the level of the way. At the top of the Whiston inclined plane there is a portion of the road (nearly two miles in length) on the exact level. About half a mile from the top of the inclined plane, the turnpike road from Liverpool to Manchester crosses the line of the Railway at an acute angle of 34 degrees, and is carried over the Railway by a substantial stone bridge, of very curious and beautiful construction, being built on the diagonal or skew principle, each stone being cut to a particular angle to fit into a particular place, the span of the arch, measured at the face, being 54 feet, while the width of the Railway underneath, measured from wall to wall, is only 30 feet,—each face of the arch extending diagonally 45 feet beyond the square. Rainhill bridge is nine miles from the Company's yard in Wapping, and it was underneath and on each side of this bridge that the experiments took place with the Locomotive Engines which contended for the premium of £500. in October, 1829.

Passing over the summit level at Rainhill, we come to the Sutton inclined plane, which descends in the opposite direction, and is similar in extent and inclination to the Whiston plane, the top level being 82 feet above the base of each plane. Par Moss is the next object of attention, the road-way across the principal part of it being formed by the deposit of heavy material (clay and stone) dug out of the Sutton inclined plane. This Moss is about 20 feet deep, and the material forming the Railway, as it was deposited, sank to the bottom, and now forms an embankment in reality 25 feet high, though only four or five feet appears above the surface of the Moss. The borders of this waste are in a state of increasing cultivation, and the carrying of the Railway across this Moss will hasten the inclosure of the whole area.

Leaving Par Moss, we soon approach the great valley of the Sankey (about half way between Liverpool and Manchester), with its Canal at the bottom, and its flats or barges in full sail passing to and fro, between the River Mersey, near Warrington, and the great Coal districts near St. Helen's. Over this valley and Canal, and over the topmasts and high peaks of the barges, the Railway is carried along a magnificent viaduct of nine arches, each 50 feet span, built principally of brick, with stone facings, the height from the top of the parapets to the water in the Canal being 70 feet, and the width of the Railway between the parapets 25 feet. The approach to this great structure is along a stupendous embankment, formed principally of clay, dug out from the high lands on the borders of the valley. Looking over the battlements, there is a fine view down the valley to the south—Winwick spire rising in the distance, and below you, the little stream of the Sankey running parallel with the Canal; while the masts and sails of the vessels, seen at intervals in the landscape where the Canal is no longer visible, present a vivid specimen of inland navigation. Immediately below you, the barges, as they approach the bridge, escape from view for a few minutes, till, having sailed under your feet, they become again visible on the opposite side of the viaduct.

On leaving the Sankey, we speedily approach the town of Newton, or rather the borough; for this ancient and loyal place sends two representatives to Parliament, under the auspices of Colonel Legh, M. P. A few hundred yards to the south of the town, the Railway crosses a narrow valley by a short but lofty embankment, and a handsome bridge of four arches, each 40 feet span. Under the eastern arch the turnpike road passes from Newton to Warrington, and beneath another arch flows a stream which turns an old corn mill, immediately below the bridge. Adjacent also, is situate one of those antique mansions, built in the ancient baronial style, whose white exterior, with black oak crossings and pointed gables, harmonizes well with the rude scenery around.

A few miles beyond Newton is the great Kenyon excavation, from which about 800,000 cubic yards of clay and sand have been dug out, part being carried to form the line of embankment to the east and west of the cutting; and the remainder, deposited as spoil banks, may be seen heaped up, like Pelion upon Ossa, towering over the adjacent land. Near the end of this cutting, the Kenyon and Leigh Junction Railway joins the Liverpool and Manchester line by two branches, pointing to the two towns respectively. This Railway joins the

Bolton and Leigh line, and thus forms the connecting link between Bolton, Liverpool, and Manchester. From the Kenyon excavation the transition is easy to the Brosely embankment, formed of the material dug out of the cutting, as before described. Moving onward, we pass over Bury-lane and the small River Gless, or Glazebrook, being arrived on the borders of the far-famed Chat Moss. This barren waste comprises an area of about twelve square miles, varying in depth from 10 to 35 feet, the whole mass being of so spongy and soft a texture that cattle cannot walk over it. The bottom is composed of clay and sand, and it is not an uninteresting, if not a very profitable speculation, to carry our ideas back to that remote period when the sea flowed over the basin of this huge fungus. There are they who profess, by examining the vegetable fibre of the Moss, to calculate its age; as the fortune-teller will cast your nativity by the furrows in your hand. No doubt this mass of vegetable matter is still increasing. The flower and the leaf of the heather still bud, grow to maturity, and fall; and the process of decomposition amalgamates the new and the old fibre; but what is thus deposited has been previously extracted from the Moss, save what has been supplied from the hydrogen and other gases absorbed and combined in this great laboratory. At a very moderate calculation, Chat Moss comprises sixty millions of tons of vegetable matter; and we shall leave to philosophers to calculate in how many centuries this weight could be drawn from the clouds and the air. Northward of the Moss, in the distance, is Tildsley Church, one of the modern Parliamentary edifices; and as we approach the eastern boundary, conspicuous on a gentle eminence to the left, is Worsley Hall, the seat of R. H. Bradshaw, Esq. M. P. so well known as Trustee for the management of the Duke of Bridgewater's Canal.

Beyond Chat Moss we traverse the Barton embankment, crossing the low lands for about a mile between the Moss and the Worsley Canal, over which the Railway is carried by a neat stone bridge. At this spot it is evident you are approaching a manufacturing district. On the banks of the Canal a great cotton factory rears its tall sides, with its hundred windows, and the fly-wheel of its steam-engine pursuing its continuous and uniform revolutions, as if symbolical of that eternal round of labour and care, of abundant toil and scanty remuneration, of strained exertion and insufficient repose, which, through day and night, through seed time and harvest, through years of civilization and ages of barbarism, have been the condition and tenure on which the existence of so large a portion of mankind has depended.

From the Barton embankment we soon arrive at Eccles, four miles from Manchester, leaving to the right the vicarage and parish church of that village. Between this place and Manchester the Railway passes at no great distance from several country seats and villas, whose rich lawns and flourishing plantations afford an agreeable variety, after the great sand hills at Kenyon, or the wide waste of Chat Moss.

The immediate approach to Manchester, by the

Railway, is through a portion of Salford, as little interesting as can well be imagined. Over the River Irwell the Railway is carried by a very handsome stone bridge, and then over a series of arches, into the Company's station in Water-street and Liverpool-road, Manchester; from which the traveller whose object is pleasure rather than business, will probably make his way, without loss of time, to the more genial attractions of the Albion Hotel, or New Bridgewater Arms.

CHAPTER IV.

MECHANICAL PRINCIPLES AND PROPERTIES, AS APPLICABLE TO RAILWAYS.

THE most obvious mechanical advantage which a Railway possesses over a common turnpike road, is to be found in its superior hardness and smoothness of surface. This comparative advantage, it is evident, can be measured by no fixed standard; though it is common to estimate it in the proportion of *seven* to *one*. It should constantly be borne in mind, however, that this ratio of superiority in favour of a Railway can only exist on an exact level. Let there be a very moderate ascent—such as on an ordinary road would scarcely attract observation—one foot in fifty for instance, and the effect of a horse on a Railway is at once reduced to about one-fifth of its effect on a horizontal plane; and on arriving at such an inclination, with a load calculated for a *level*, the horse would be unable to move a single yard with the utmost exertion of its strength; while on a common road, undulations such as I have stated are of ordinary occurrence—a horse being able to exert a sufficiently increased power as he ascends the eminence, and relieving himself as he descends on the opposite side. But let it not be imagined that the *absolute* resistance occasioned by a certain inclination, is more on a Railway than on a turnpike road: it is precisely the same, and this peculiarity in the *comparative* result may be easily

7 h-1

explained. The resistance on a Railway to the progress of the carriage wheels (sometimes called the rolling friction) being only about one-seventh what it is on common roads, the ordinary load on a *level Railway* is *seven times* as great as the load on a turnpike road. Consequently, when the force of *gravity* is brought into operation by an ascending plane, this opposing force (of gravity) being proportioned to the *load*, will be seven times as great as on a turnpike road.

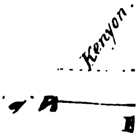
Most of the Railways hitherto constructed have had an inclination *downwards*, being for the conveyance of coal from the pits to the river side. For purposes of general traffic, however, and where there is any thing like an equality of tonnage passing in both directions, it cannot be too constantly kept in view, that to render the moving power uniformly effective, and to maintain for the Railway its full comparative advantage over the common roads, it must, as far as practicable, be *level*. In the Liverpool and Manchester line, this object has been in a great measure attained, as will appear from the annexed section. From the top of the Liverpool Tunnel to Manchester, with the exception of two inclined planes at Rainhill (one ascending and the other descending at an inclination of 1 in 96, and where some assistant power must be used), there is no greater inclination than in the ratio of about 1 in 880; and since the advantage on the descending side will nearly counterbalance the disadvantage in ascending so gradual a slope, the Railway may be regarded, for practical purposes, as nearly horizontal.

RPOO

.. *Perpe*

... *Perp*

ve the



IOTHECA BODLE

A level line being attained, it is scarcely of less importance that the Railway should be *straight*, or at least free from any *abrupt curves*. As carriages are kept on the rail by flanges on the wheels, it is obvious that where the curves are quick, the friction on the sides of the rails, and consequent retardation, must be very great. This is a point which, till lately, has not been sufficiently attended to. In the Liverpool and Manchester Railway, the curves seldom exceed a deviation from a straight line of more than 4 inches in 22 yards; forming a segment of a circle, which, if extended, would embrace a circumference of fifteen miles. The setting out of the curves on the ground is a work requiring considerable skill and exactness, and the manner in which this is performed affects the real efficiency of the Railway no less than it does the style and beauty of its appearance.

4 ins in 22

The material of which the rails were to be composed, whether of *cast* or of *forged* iron, was a matter of some importance. Each description of rail has its advocates; but after due consideration, and inquiry into their respective merits, the Directors determined to adopt the forged or rolled iron rail, in lengths of five yards each, made after Mr. Birkinshaw's pattern, as described in Mr. Nicholas Wood's excellent book on Railways. A similar rail is used on the Darlington way, but somewhat lighter; the Darlington rail weighing 28 lb. and the Liverpool and Manchester 35 lb. per lineal yard. The rails are supported every three feet on stone blocks, each block containing nearly four cubic feet of stone. Two holes, six inches deep and an inch diameter, are drilled in each block, and into these are driven oak plugs; and the cast-iron chairs or pedestals, to which the rail is immediately fitted and fastened, are firmly spiked down to the oak plugs; forming, altogether, a construction of great solidity and strength. On the embankments, where the foundation may be expected to subside, the rails are laid on oak sleepers.

But supposing the Railway to be completed, of the most improved construction and the best material, the kind of *carriage* to be used, and the *power* to be employed, afford scope for ample discussion and the most conflicting opinions; for so new, or so little understood, it would seem, is the application of mechanical principles to a Railway, that as much difficulty presented itself to the Directors, in their endeavours to come to a conclusion on these points, as if the matter at issue involved a question of law or metaphysics. On the first announcement of a projected Railway, on a complete scale, from Liverpool to Manchester, the ingenuity of speculative mechanics anticipated the most astonishing results to be obtained from the most undeniable and acknowledged principles. It was understood to have been previously ascertained by Coulomb and Professor Vince, that *friction* (as applicable to carriages) was the same at all velocities. It seemed to follow, that on a level Railway, where friction constituted the *whole* resistance, the inert mass being once put in motion, it would be as easy to travel *twenty* miles per hour, as *five*. The fallacy of this idea arises in a good measure from a misconception of the operation of the principle alluded to—that *the friction is the same at all velocities* —from which it appears to have been inferred, that if you provide a power sufficient to overcome the friction at a very slow speed, and call that power *one*, and then apply additional power to augment the speed *ten* fold, you may at pleasure relinquish this additional power, and continue to move at the *ten* fold speed with the power *one*. The truth is, however, that for every ratio of increased *speed* you must exert increased *power*, and must *continue* to use it. On a level Railway, friction constitutes the *whole* resistance; and if it require a certain power to overcome such resistance at two miles per hour, it will require ten times that power to overcome the resistance at twenty miles per hour, and it will require the *increased* power to be *continued* as long as the speed is intended to be kept up. If to convey a certain load at the rate of five miles per hour requires a Locomotive Steam Engine with a boiler and pistons of a certain given area, then to move the same load at the rate of fifteen miles per hour, the boiler and cylinders (if there be no improvement in the construction) must be *three* times the *area*. In this latter case, therefore, there will be *three times* the steam (or power) expended *per hour*, but the *journey* will be effected in *one-third* the time: the *whole* expenditure of steam (or power), therefore, in overcoming the friction will be nearly the same, whether the journey be performed at a slow or a quick speed. We will suppose, for illustration, that a *weight* has to be *raised*, instead of *friction* to be *overcome*—the same principle will hold good. If it require a certain power to raise a ton weight *one hundred* feet high in ten minutes, it will require *ten* times the power to raise it the same height in one minute—that is, at ten times the speed; yet a ton is a ton, at all velocities, exactly as *friction* is the same, whatever the speed.

There is another error on the subject of friction, to which it may be as well briefly to advert. Mr. Rankin, in his publication on Railways,* lays it down as a principle, that "the friction of wheel carriages is equal in equal times;" and in proof of this position, details several experiments with a carriage drawn by a weight descending from a pulley, which weight, he found, fell according to the ascertained law of gravity, accelerating in the known ratio, in equal portions of time. It appears to me that the result, as stated, proves that friction is equal *in equal spaces*, and *not in equal times*. Mr. Rankin does not give either the moving weights, the load drawn, or the velocity, as not being necessary to determine the principle. I will suppose a case, therefore, to illustrate my position. A weight, by the law of gravity, will fall—

16 feet in the 1st second of time,
48 feet in the 2d second of time,
80 feet in the 3d second of time.

Now the same weight, with the load or carriage attached to it by means of a rope and pulley, we will suppose to fall—

5 feet in the 1st second of time,
15 feet in the 2d second of time,
25 feet in the 3d second of time,

Accelerating as before, according to the law of gravity.

---

* A Popular Exposition of the Effect of Forces on a Railway, with some Experiments on Friction. By David Rankin, Esq. Glasgow, 1828.

Thus we have a descent, in *equal times*, of 5, 15, 25, instead of 16, 48, 80. That is, the *friction* of the carriage caused the weight to fall in the first *second* only 5 feet instead of 16, being a *retarding* force of 11. In the second period the fall was 15 instead of 48, being a retarding force of 33, or in the proportion of 15 to 5. In the third *second* of time the fall was 25 feet instead of 80—being a retarding force of 55—being as 25 to 5, or exactly in proportion to the *spaces* passed over, and not at all according to the *times;* in perfect conformity, however, with the law of gravity. In Mr. Rankin's experiment the friction was a uniformly retarding force, which we have supposed to be 11 out of 16; but, whether it were 11 or 3 in the first 16 feet, it would be the same in *every* 16 *feet:* the friction, therefore, by the experiment was equal in equal *spaces.* On the other hand, supposing the friction to be equal in equal *times*, a power which would move a carriage six miles in one hour, would encounter only *one-fourth* the friction in traversing the same six miles in *one-quarter* of an hour, which would be very convenient, if it were the fact. But experiment corroborates the doctrine, that the same resistance has to be overcome, and therefore the same power must be expended, in traversing a certain *space*, whatever be the *time*—whether you take *one hour* or three to accomplish it.

Of course, in laying down this general rule as an approximation to the truth, we suppose a perfect Railway. If the road present considerable inequalities or obstructions, the greater the speed, the greater will be the resistance, from the shocks to be encountered.

Moreover, at great velocities the resistance of the *air* must not be left out of the calculation. At ten miles per hour it has been found, by experiment, that the resistance of the atmosphere is about half a pound weight on a square foot of flat surface; at fifteen miles the resistance is 1 lb. per square foot; and at twenty miles about 2 lb. per square foot; the increased resistance being nearly as the squares of the velocities. Now if we suppose the moving power calculated to draw, at twenty miles per hour, one carriage weighing 4 tons, and presenting in front a surface of 20 square feet, the resistance of the air would be $20 \times 2 = 40$ lb., or 10 lb. per ton drawn; being about as much as the *friction*, and consequently *doubling* the whole resistance. In practice, it will probably be expedient to fasten a *train* of carriages to one moving power, in which case the *first* waggon, or the Engine itself, will bear the brunt of the air's resistance; which, considered in proportion to the whole weight drawn, and avoiding, as far as may be, square flat surfaces in front of the procession, will be less important. On the other hand, it seems probable that a further modification must be admitted at very high speeds; for we can easily imagine a velocity, where the *projectile force* must be so great as very much to *diminish the gravity*, and consequently the friction. But again, as we are acquainted with no convenient power but steam, with which to effect rapid motion—and since steam loses part of its force from a very quick transmission through the cylinders—or since, if you keep the velocity of your piston moderate, you must increase your speed by a complication of wheels, or a diminution of your cranks, in which case the loss by the friction of the rubbing parts would be greater than by the quick movement of the pistons, any gain by the diminution of gravity at high velocities, will be more than counterbalanced by the mechanical disadvantages we have stated; bringing out the practical result, within a certain range for weight and speed, pretty nearly in conformity with the rule as above laid down—subjct, however, to exceptions and irregularities, tending to prove, that when the construction of an Engine is adapted to a quick speed and a light load, you cannot, with proportionate advantage, substitute a heavy load and a slow speed; while it would be equally unavailing, with an Engine calculated for a heavy load and a slow pace, to attempt to substitute a light load and a high speed.

But without dwelling any longer on the difficulty of reducing, with minute exactness, abstract principles to practical operation, it will easily be imagined that the consideration of the *kind of power* to be employed on the Railway occupied no small portion of the Directors' time and attention: whether horses—or Locomotive Engines—or Fixed Engines, drawing the load, by means of ropes, from one station to another. Each of these modes had been tried, and each had its advocates, for in this case experience had by no means settled the point at issue.

Multifarious were the schemes proposed to the Directors, for facilitating Locomotion. Communications were received from all classes of persons, each recommending an improved power or an improved carriage; from professors of philosophy, down to the humblest mechanic, all were zealous in their proffers of assistance; England, America, and Continental Europe were alike tributary. Every element and almost every substance were brought into requisition, and made subservient to the great work. The friction of the carriages was to be reduced so low that a silk thread would draw them, and the power to be applied was to be so vast as to rend a cable asunder. Hydrogen gas and high-pressure steam—columns of water and columns of mercury—a hundred atmospheres and a perfect vacuum—machines working in a circle without fire or steam, generating power at one end of the process and giving it out at the other—carriages that conveyed, every one its own Railway—wheels within wheels, to multiply speed without diminishing power—with every complication of balancing and countervailing forces, to the *ne plus ultra* of perpetual motion. Every scheme which the restless ingenuity or prolific imagination of man could devise was liberally offered to the Company: the difficulty was to choose and to decide.

The great theatre of *practical* operations on Railways was on the Stockton and Darlington line, and on the Railways in the vicinity of Newcastle-on-Tyne. All the established modes of conveying carriages on Railways were there exemplified—Horses, Locomotives, and Fixed Engines. Facts were wanted to lead to a correct decision, and personal observation seemed necessary, in order to arrive at a satisfactory result. The Directors accordingly appointed two of their own body, accompanied by the writer, to proceed to Darlington and the neighbourhood of Newcastle, to obtain on the spot, the requisite information, and to report the same to the Board, with their opinion on the subject. This journey of inspection took place in the beginning of October, 1828, and the Deputation returned with a fund of information; but of so mixed, and in some respects of so contradictory a nature, that the great question as to the comparative merits of Locomotive and Fixed Engines was as far from being settled as ever. One step was gained. The Deputation was convinced, that for the immense traffic to be anticipated on the Liverpool and Manchester line, horses were out of the question. The debateable ground being thus narrowed, how was the remaining point to be decided? Was a capital of £100,000. to be invested in Stationary Engines or in Locomotives? The Directors resolved to obtain the assistance of two professional Engineers, who should visit the Darlington and Newcastle Railways, carefully examine the working of the two species of mechanical power, taking note of the advantages and disadvantages of each, make an accurate calculation of the *cost* of both modes of conveyance, and report to the Board fully on the whole subject.

James Walker, Esq. of Limehouse, and J. U. Rastrick, Esq. of Stourbridge, being severally applied to for the purpose, undertook the office assigned to them. On the 12th of January, 1829, they attended at the Board of Direction in Liverpool, previous to their setting out on their professional tour. On the

9th of the following March, their separate *Reports* on the comparative merits of the two systems of moving power, were laid before the Directors, and ordered to be printed.

It may be supposed that the great question was now finally set at rest, and that the Directors would have no further difficulty in coming to a decision on the points at issue. Just the reverse. The advantages and disadvantages of each system, as far as deduced from their own immediate observation, were fully and fairly stated, and, in the opinion of the Engineers themselves, were pretty equally balanced. The cost of an establishment of Fixed Engines between Liverpool and Manchester, they were of opinion, would be something greater than of Locomotives, to do the same work; but the *annual charge*, including interest on capital, they computed would be less on a system of Fixed Engines than with Locomotives. The cost of *moving* a ton of goods thirty miles, that is from Liverpool to Manchester, by Fixed Engines, they estimated at 6.40d., and by Locomotives at 8.36d., supposing in each case a profitable traffic *both ways*. But with a system of Locomotives, the cost of the first establishment need only be proportioned to the demands of the trade; while with Stationary Engines, an outlay for a complete establishment would be required in the first instance. And it was further to be considered, that there appeared more ground for expecting *improvements* in the construction and working of Locomotives than of Stationary Engines. On the whole, however, and looking especially at the computed annual charge of working the road on the two systems on a large scale, Messrs. Walker and Rastrick were of opinion that ***Fixed Engines*** were preferable, and accordingly recommended their adoption to the Directors.

On a careful consideration of the real state of the case at this moment, it will not be matter of surprise that the Directors still felt themselves unable to come to a decision on the subject; more especially when it is remembered that Mr. Stephenson, the Company's Engineer, was decidedly, as he had uniformly been, in favour of Locomotive Engines, which he was confident would be found to be the most economical and by far the most convenient moving power that could be employed. On the whole, therefore, the Directors found themselves in pretty much the same situation as they were before the recent survey was undertaken. The leaning on the part of a majority of the Directors was in favour of Locomotives, provided they could be constructed of adequate power and at a less weight than the travelling Engines then in use, which were generally 8 to 9 tons in weight, and some still heavier; the consequence of which was no small injury to the Railways, and proportionate expense in keeping the road in repair. And further, it was quite essential, according to the provisions of the Railway Act, that they should not *smoke.* The Directors determined to obtain, if possible, a Locomotive Engine of improved construction, that should comply with these conditions. Mr. Harrison had for some time been of opinion, that the excitement of a reward, publicly offered by the Company, would be the most likely means to obtain for them what they were in search of. In this opinion his brother Directors now coincided; and accordingly they resolved, on the 20th of April, 1829, to offer a premium of £500. for the most improved Locomotive Engine, subject to certain stipulations and conditions, a copy of which I subjoin:—

" *Railway Office, Liverpool, 25th April,* 1829.

" STIPULATIONS AND CONDITIONS

" *On which the Directors of the Liverpool and Manchester Railway offer a premium of £500. for the most improved Locomotive Engine.*

" 1st.—The said Engine must " effectually consume its own smoke," according to the provisions of the Railway Act, 7th Geo. IV.

" 2d.—The Engine, if it weighs six tons, must be capable of drawing after it, day by day, on a well-constructed Railway, on a level plane, a train of Carriages of the gross weight of twenty tons, including the Tender and Water Tank, at the rate of ten miles per hour, with a pressure of steam in the boiler not exceeding 50 lb. on the square inch.

" 3d.—There must be two Safety Valves, one of which must be completely out of the reach or control of the Engine-man, and neither of which must be fastened down while the Engine is working.

" 4th.—The Engine and Boiler must be supported on springs, and rest on six wheels; and the height, from the ground to the top of the chimney, must not exceed fifteen feet.

" 5th.—The weight of the Machine, *with its complement of water* in the boiler, must, at most, not exceed six tons; and a Machine of less weight will be preferred, if it draw *after* it a *proportionate* weight; and if the weight of the Engine, &c. do not exceed *five tons*, then the gross weight to be drawn need not exceed fifteen tons; and in that proportion for Machines of still smaller weight—provided that the Engine, &c. shall still be on six wheels, unless the weight (as above) be reduced to four tons and a half, or under, in which case the boiler, &c. may be placed on four wheels. And the Company shall be at liberty to put the boiler, fire tube, cylinders, &c. to the test of a pressure of water not exceeding 150 lb. per square inch, without being answerable for any damage the Machine may receive in consequence.

"6th.—There must be a mercurial gauge affixed to the Machine, with index rod, showing the steam pressure above 45 lb. per square inch; and constructed to blow out a pressure of 60 lb. per inch.

"7th.—The Engine to be delivered complete for trial, at the Liverpool end of the Railway, not later than the 1st of October next.

"8th.—The price of the Engine, which may be accepted, not to exceed £550., delivered on the Railway; and any Engine not approved, to be taken back by the owner.

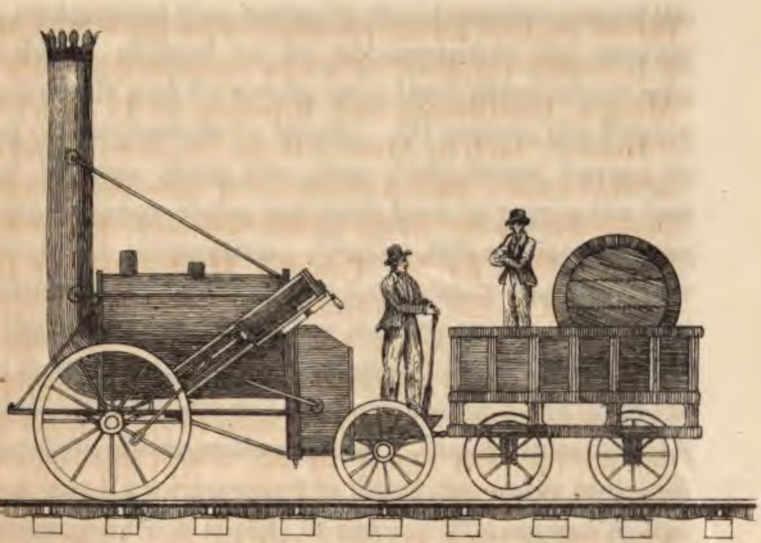
"N. B.—The Railway Company will provide the *Engine Tender*, with a supply of water and fuel, for the experiment. The distance within the rails is four feet eight inches and a half."

Meanwhile, all measures relative to the moving power were suspended, till the result of the trials of the specimen Engines should be ascertained. On the 6th of October, which was the day subsequently fixed for the trials, four Locomotive Steam Engines were on the ground appointed at Rainhill, a level portion of the Railway, about nine miles from Liverpool. That the Directors might come to the most correct decision on the merits of the different machines produced, they had engaged the professional assistance of Mr. Rastrick, of Stourbridge, and Mr. Nicholas Wood, of Killingworth, both Engineers of great practical knowledge; aided by the co-operation of John Kennedy, Esq. of Manchester, who kindly complied with the request of the Directors, that he would be one of the Judges, on the occasion.

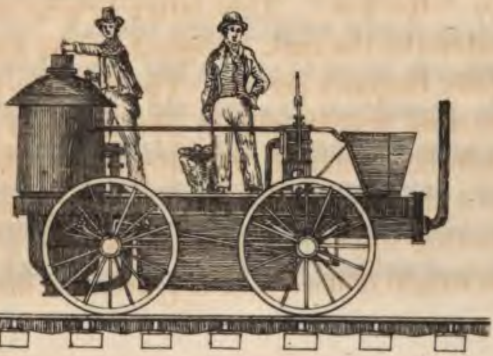
The Steam Engines which were entered on the lists to contend for the premium, were the "Novelty," a beautiful machine, of a new construction, built by Messrs. Braithwaite and Ericsson, of London; the "Rocket," built by Messrs. Robt. Stephenson and Co. of Newcastle, with a boiler of a new construction, suggested by the writer of this account; the "Sans Pareil," built by Mr. Timothy Hackworth, of Darlington; and the "Perseverance," by Mr. Burstall, of Leith.

The peculiarity of the exhibition, on the several days of trial, attracted a large concourse of spectators; and the unexampled speed of the "Novelty" and the "Rocket" excited universal surprise and admiration. The trial of these Engines, indeed, may be regarded as constituting a new epoch in the progress of mechanical science, as relating to locomotion. The most sanguine advocates of travelling Engines had not anticipated a speed of more than ten to twelve miles per hour. It was altogether a new spectacle, to behold a carriage crowded with company, attached to a self-moving machine, and whirled along at the speed of thirty miles per hour. The contest for the premium was principally between the "Novelty" and the "Rocket." This latter Engine was the first to undertake the task assigned by the Judges, as a test of the Engine's power. The distance appointed to be run was seventy miles; and it was a condition, that when fairly started, the Engine should travel on the road at a speed of not less than ten miles per hour, drawing after it a gross weight of 3 tons for every ton weight of itself. The prescribed distance it should

ROCKET, LOCOMOTIVE.



NOVELTY, LOCOMOTIVE.



be understood was, owing to the circumstances of the Railway, obliged to be accomplished by moving backwards and forwards, on a level plane of one mile and three-quarters in length. Of course, the Engine had to pass along the plane forty times, having to make as many stops, and each time to regain the lost speed and momentum. On the 8th of October, the "Rocket," weighing 4 tons 5 cwt. including the water in the boiler, started on her journey at about half-past ten in the morning, and performed the first thirty-five miles in three hours and twelve minutes, being nearly at the rate of eleven miles an hour. About a quarter of an hour was then consumed in filling the water tank and obtaining a fresh supply of coke. The second thirty-five miles were performed in two hours and fifty-seven minutes, or at the rate of twelve miles per hour, including stoppages. The whole time, from the first starting to the final arrival, was under six hours and a half. The speed over the ground, with the prescribed load, was frequently eighteen miles per hour, and occasionally upwards of twenty. The whole performance was considerably greater than required by the stipulations, or than had hitherto been accomplished by a Locomotive Engine.

The "Novelty" was the next Engine which undertook the appointed task; but owing to some derangement having occurred in her pipes or machinery, she was obliged to stop almost at the commencement of the task assigned. Another day was appointed, and another derangement took place. It became evident, therefore, she was not in a state of completeness to warrant the Proprietors in prolonging the contest. Accordingly, they informed the Judges that they withdrew from the competition on the present occasion; having, nevertheless, full confidence in the merits and principle of the Engine, and in its relative performance, when they should have repaired the defects in the structure or workmanship of the machine.

The Darlington Engine, the "Sans Pareil," was the next on the list; but being 5 cwt. above the weight prescribed in the conditions, it may not be necessary to discuss her merits in other respects. Mr. Burstall, after consideration, withdrew from the contest, leaving the field to the "Rocket." The Report of the Judges corresponded with the above statement, and the Directors accordingly awarded the premium to the writer of this account and the Messrs. Stephensons, to whose excellent construction of the machinery I was much indebted for the favourable award of the Umpires.

From this date, the question between Locomotive and Fixed Engines must be considered as practically settled. The fitness of Locomotives for the purposes of *travelling*, at almost any speed that could be desired, was strikingly exemplified; and the importance of this circumstance was duly estimated; the conveyance of passengers between Liverpool and Manchester having long been considered a valuable branch of the undertaking. There still remained one point to be settled—I allude to the *kind of power* to be employed in ascending the inclined planes of Whiston and Sutton. These planes are each a mile and a half long, with an inclination of three-eighths of an inch to a yard, being a rise of 1 in

96. Stationary Engines on the summit, with ropes passing over sheaves or pullies along the whole ascent, are the means resorted to at the inclined plane in the Liverpool Tunnel; also on the Darlington inclined planes, and at the collieries in the north. It was quite evident, however, that such a plan of operations in the centre of the Liverpool and Manchester line, with the interruption to be expected from a *change* of the moving power, to say nothing of the danger always to be apprehended from a system of ropes and pullies, was to be avoided, if possible. It became an object, therefore, of no small interest to ascertain the power of the new Locomotives on the planes in question; and in the first place, as the effective power of the Engine is necessarily limited by the adhesion of the wheels on the rails (in as much as if a force be exerted beyond that point, the wheels will turn round, while the carriage will remain stationary), it was important to know whether this difficulty was likely to occur on the planes in question. It has been ascertained that the adhesion of the Engine wheels (as now constructed with wrought-iron tires) on wrought-iron rails is equal to $\frac{1}{20}$th of the weight of the machine, in the most unfavourable state of the rails. If the Engine weigh $4\frac{1}{2}$ tons, the adhesion on the four wheels would be $\frac{1}{20}$th of that weight, or about 500 lb.; or supposing—which is frequently the case—that the machinery is only connected with two wheels, then, if the weight be equally divided, the adhesion will be = 250 lb.; which, multiplied by 200 (the *friction* being only $\frac{1}{200}$th of the *gravity* of the load), gives 22 tons as the load, com-

mensurate with the adhesion, in the most unfavourable state of the rails,—about 40 tons being the adhesive load in an average state of the rails. Now these being the data, an inclined plane rising one yard in a hundred, will present no impediment on the ground of adhesion, provided the system be to maintain the same speed throughout the journey; for supposing, as above, that the adhesion of the Engine wheels on the level, be = 250 lb., it will be the same on the inclined plane, minus $\frac{1}{100}$th part (2½ lb.); a difference so small as to occur, every day, in the varying states of the rails, and quite unnecessary to be taken into the calculation. The question to be decided, therefore, was the *power* of the Engine to take a load up the inclined plane, the adhesion being equal to the power, at similar speeds. For instance, 7 tons on an inclined plane rising one in a hundred, is a proportionate load to 30 tons on a level, at fifteen miles per hour, the weight of the Engine being 4½ tons, as explained hereafter. But if it be attempted to take 30 tons up the plane, by going proportionably *slower*, the *power* of the Engine might do this, but the adhesion of the wheels would be insufficient, and they would turn round, while the Engine stood still, because 30 tons on the inclined plane = 99 tons on a level, and we have supposed the adhesion to be equal to 40 tons on a level. It follows, therefore, either that the Engine must be worked *below* the adhesiveness of the wheels on the level, or you cannot increase the proportionate load, by diminishing the speed on the inclined plane.

During the trials for the premium, at Rainhill, the

"Rocket" frequently ascended the Whiston inclined plane, with a carriage holding twenty to thirty passengers, at a speed of fifteen to eighteen miles per hour; and the ease and regularity with which this was effected produced a general and confident impression, that even up the inclined planes, the Locomotive Engine would be the power employed. Indeed, the feeling at the moment, was very prevalent, that it was immaterial whether the Engine travelled up an inclined plane, or on a level; and various schemes were speedily in agitation for converting turnpike roads into Railways, regardless of the ordinary inequalities of the ground. Time and reflection will correct a notion so plausible, but yet so erroneous; otherwise the most grievous disappointments will be the consequence. Dazzled and gratified with the spectacle of the Engine, with her carriage and twenty passengers, moving up the plane at a speed hitherto not attained by the swiftest mails, the spectator forgot, or was not aware, that she would have taken *four* carriages, each with its score of passengers, at the *same speed*, on *a level;* or, in more general terms, that the *annual performance* of a Locomotive Engine, on a *level* Railway, would be about four times as great as on an inclined plane, rising one yard in a hundred. I have said *about* four times; for the comparative ratio will depend much on the *weight* of the Engine, the speed of travelling, and the construction of the carriage wheels and axles. The more power you can comprise in the same *weight* of Engine, the greater will be her *comparative* performance on an *inclined plane;* and on the other hand, the greater the improvement in wheels and axles, and the more the *friction* is *diminished*, the greater will be the *comparative* performance on a *level*. Mr. Nicholas Wood, in his book on Railways, estimates the friction of loaded waggons at $\frac{1}{200}$ of the load moved; that is, that one pound weight, suspended over a pulley, would draw 200 lb. on a level Railway. Since Mr. Wood made his experiments, further improvements have been made in the construction of wheels and axles; perhaps to the extent of 25 per cent., leaving the amount of friction on a level Railway $\frac{1}{250}$ of the load moved, or 9 lb. per ton. This ratio, however, allows nothing for the resistance of the air: it supposes both waggons and Railway in very complete order, and the line an absolute and undeviating level. Moreover, experiments on the *friction* of waggons have generally been made on *single* waggons; and there is reason to believe, that the resistance offered by a number of waggons fastened to each other is greater than the proportionate weight would indicate: and this may be accounted for by the separate carriages being *out of square*, with reference to each other, thereby occasioning a straining and lateral friction. On the whole, perhaps, we shall come sufficiently near the truth if we adopt Mr. Wood's ratio of $\frac{1}{200}$ as the amount of resistance to a train of waggons on a level way, under ordinary circumstances of rails and waggons, wind and weather. The inclination of the Whiston plane being 1 in 96, the opposing force of gravity of any load on its ascent will be $\frac{1}{96}$th of the whole weight moved; or if we say $\frac{1}{100}$th part, the resistance by ***gravity*** will be ***double*** the resistance by ***friction.*** It will follow, then, that if a Locomotive Engine, weighing 4 tons 10 cwt. is exactly able to draw after it 30 tons weight on ***a level,*** at fifteen miles per hour (which I estimate to be the power of an Engine on the " Rocket" principle, with the latest improvements), the same Engine will draw only 7 tons, at the ***same speed,*** up an ***inclined plane*** rising one yard in a hundred. This result may be illustrated as follows:—

The load ***drawn*** on the inclined plane is declared to be.. 7 tons.

Now the ***additional*** resistance (by ***gravity)*** is double the resistance by ***friction;*** then, as the load drawn is 7 tons, the ***gravity*** of the plane equals the ***friction*** of ....14 tons.

But the Engine weighs 4 tons 10 cwt., and is opposed by a force of gravity equal to the ***friction*** of double that weight, or.. 9 tons.

Therefore 7 tons on the ***inclined plane*** equals the draught of .. } 30 tons on a ***level,*** at 15 miles per hour.

Or the same result may be brought out by another process, as follows:—The gross weight proposed to be drawn on ***a level*** is 30 tons, at fifteen miles per hour, on which the friction, estimated at $\frac{1}{200}$, = 336 lb.

Then, on an inclined of 1 in 100, the gross weight is declared to be 7 tons, on which the friction, estimated at $\frac{1}{200}$, is............ = 78.4 lb.
Resistance by gravity, $\frac{1}{100}$ of 7 tons......... = 156.8 „
Resistance by gravity on 4½ tons, the weight of the Engine at $\frac{1}{100}$ .... = 100.8 „
= 336 lb.

The resistance to be overcome, in both instances, being 336 lb., at fifteen miles per hour, besides the *friction* of the Engine, which does not enter into the calculation in either case—the *effective performance* being what is required for all practical purposes. If a *slower* speed be submitted to, a heavier load may be drawn on the level, and the performance on the inclined plane (if the adhesion be sufficient) will be found, by the same formula, to be *more* than *proportionably* greater; the resistance by *gravity* of the Engine being a fixed quantity, but smaller, *comparatively*, as the load drawn is *greater*. Thus an Engine of the same weight being exactly able to draw 45 tons on a level, at ten miles per hour, would take 12 tons on the inclined plane at the same speed.

Because the *load* on the incline being......... 12 tons,
The resistance by gravity is double that by friction, or......... .... 24 „
And the resistance by gravity of the Engine being equal to double its weight on a level = 9 „
= 45 tons,

on a level.

I am aware that the recent performance of Locomotives, on our inclined planes, has been considered greater than in the ratio I have given: it is very possible, however, that the attained speed and momentum of the Engine and carriages, *before commencing* the ascent, have not been taken into the account. The "Comet" Locomotive (a new Engine, on the "Rocket" principle) had to ascend the Whiston inclined plane with about 26 tons behind her. With this load, she attained a speed of sixteen or eighteen miles per hour, on the level way, *before coming to the ascent*. Assisted by this momentum, she accomplished the task: her speed, however, diminished from sixteen or eighteen miles to about three or four miles per hour, before she reached the top; the distance being one mile and a half, and having sufficient steam the whole time. Now it would be quite erroneous, from these data, to take the average speed between three miles and eighteen, and to infer that the power of the Engine was equal to convey a load of 26 tons, up an inclination of 1 in 96, at ten miles and a half per hour; her real power, as shown by the experiment, and estimated in a *continuing* speed with the load as stated, being only three or four miles, or proportionate to about 7 tons up the same plane, at fifteen miles per hour. It becomes worthy of remark, therefore (connected with this branch of our subject), that in considering the section for a projected Railway, the *length* of the inclined planes should be taken into the account, as well as the steepness of ascent; since, on a plane half a mile long, it is evident much more may be accomplished than on one, three or four times that length.

The actual cost of conveyance by Railway and Locomotive Engines is perhaps not yet very accurately ascertained. The necessity of using *coke* instead of *coal*, in order to comply with the Parliamentary restrictions as to smoke, will increase, in some degree, the expense of the Engines on the Liverpool and Manchester line.* Until the late trials, it was doubtful how far coke could be used at all, except at a very serious sacrifice of the power and efficiency of the Engine. By an improved construction of machine, this difficulty is in a great measure obviated; and the difference in expense between coke and coal, which still subsists, should be cheerfully borne by Railway Companies, to relieve the community at large from the volumes of dense black smoke, with which, it is to be feared, Railways will be disfigured, where there is no Parliamentary enactment, to protect the public from so serious and unnecessary a nuisance.

---

* The consumption of coke, by the different Engines in the ordinary business and working of the Railway, has yet to be determined by experience. Messrs. Braithwaite and Ericsson, the patentees of the "Novelty," have contracted with the Company to furnish an Engine not exceeding 5 tons weight, which shall draw 40 tons gross from Liverpool to Manchester in two hours (being assisted up the inclined plane), the consumption of coke not to exceed half a pound weight per ton drawn per mile.

CHAPTER V.

CONSIDERATIONS—MORAL—COMMERCIAL—ECONOMICAL.

BEFORE concluding our account of the Railway, we shall take a single glance at the position we occupy, and the probable changes, whether for good or evil, which may be expected to occur (as the consequence of our operations) in the state and circumstances of the community around. The first and most obvious result must needs be a great revolution in the established modes of conveyance, both for merchandise and passengers, between Liverpool and Manchester; and consequently in the private interests of a large class of persons, who have been engaged, directly or indirectly, in the coaching or carrying business. An undertaking like the Liverpool and Manchester Railway, completed at a cost, including its machinery and carriages, of upwards of £800,000. for a line of thirty-one miles, and professing to be decidedly superior to existing establishments, cannot be brought imperceptibly or silently into operation. But though a great change must take place in the application of capital, and the distribution of revenue, amongst large companies and wealthy proprietors, the effect on the whole, with reference to the employment of the labouring classes, may be considered as decidedly favourable. It has frequently been matter of regret, that in the progress of mechanical science, as applicable to trade and manufactures, the great stages of improvement are too often accompanied with severe suffering to the industrious classes of society. The machinery of the present day continually supersedes that of a few years back; and as the substitution of mechanism for manual labour is the object generally aimed at, immediate privation to the labouring community seems the inevitable result. It has consequently been a subject of speculation, how far the rapid extension of manufactures, by the instrumentality of successive improvements in machinery, is advantageous to a country, as regards its moral and social condition. I recollect that, during the progress of the Railway Bill through Parliament, when some members of the Railway Committee waited on Lord Harewood, and urged the advantages to trade and manufactures to be anticipated from the facilities of communication to be afforded by the Railway, his Lordship demurred at once to our proposition, that any new impetus to manufactures *would* be advantageous to the country. And before this point can be settled, we must determine the broader and more general question, whether it be desirable that a nation should continue in the quiet enjoyment of pastoral or agricultural life, or that it should be launched into the bustle and excitement of commerce and manufactures. We must refer to the history of the world, and compare the characters and capabilities for happiness, of different ages and nations. We must decide between qualities of different kinds and claims of opposite characters—between the simple

" Rocket" frequently ascended the Whiston inclined plane, with a carriage holding twenty to thirty passengers, at a speed of fifteen to eighteen miles per hour; and the ease and regularity with which this was effected produced a general and confident impression, that even up the inclined planes, the Locomotive Engine would be the power employed. Indeed, the feeling at the moment, was very prevalent, that it was immaterial whether the Engine travelled up an inclined plane, or on a level; and various schemes were speedily in agitation for converting turnpike roads into Railways, regardless of the ordinary inequalities of the ground. Time and reflection will correct a notion so plausible, but yet so erroneous; otherwise the most grievous disappointments will be the consequence. Dazzled and gratified with the spectacle of the Engine, with her carriage and twenty passengers, moving up the plane at a speed hitherto not attained by the swiftest mails, the spectator forgot, or was not aware, that she would have taken *four* carriages, each with its score of passengers, at the *same speed*, on *a level;* or, in more general terms, that the *annual performance* of a Locomotive Engine, on a *level* Railway, would be about four times as great as on an inclined plane, rising one yard in a hundred. I have said *about* four times; for the comparative ratio will depend much on the *weight* of the Engine, the speed of travelling, and the construction of the carriage wheels and axles. The more power you can comprise in the same *weight* of Engine, the greater will be her *comparative* performance on an *inclined plane;* and on the other hand, mensurate with the adhesion, in the most unfavourable state of the rails,—about 40 tons being the adhesive load in an average state of the rails. Now these being the data, an inclined plane rising one yard in a hundred, will present no impediment on the ground of adhesion, provided the system be to maintain the same speed throughout the journey; for supposing, as above, that the adhesion of the Engine wheels on the level, be = 250 lb., it will be the same on the inclined plane, minus $\frac{1}{100}$th part (2½ lb.); a difference so small as to occur, every day, in the varying states of the rails, and quite unnecessary to be taken into the calculation. The question to be decided, therefore, was the *power* of the Engine to take a load up the inclined plane, the adhesion being equal to the power, at similar speeds. For instance, 7 tons on an inclined plane rising one in a hundred, is a proportionate load to 30 tons on a level, at fifteen miles per hour, the weight of the Engine being 4½ tons, as explained hereafter. But if it be attempted to take 30 tons up the plane, by going proportionably *slower*, the *power* of the Engine might do this, but the adhesion of the wheels would be insufficient, and they would turn round, while the Engine stood still, because 30 tons on the inclined plane = 99 tons on a level, and we have supposed the adhesion to be equal to 40 tons on a level. It follows, therefore, either that the Engine must be worked *below* the adhesiveness of the wheels on the level, or you cannot increase the proportionate load, by diminishing the speed on the inclined plane.

During the trials for the premium, at Rainhill, the

" Rocket" frequently ascended the Whiston inclined plane, with a carriage holding twenty to thirty passengers, at a speed of fifteen to eighteen miles per hour; and the ease and regularity with which this was effected produced a general and confident impression, that even up the inclined planes, the Locomotive Engine would be the power employed. Indeed, the feeling at the moment, was very prevalent, that it was immaterial whether the Engine travelled up an inclined plane, or on a level; and various schemes were speedily in agitation for converting turnpike roads into Railways, regardless of the ordinary inequalities of the ground. Time and reflection will correct a notion so plausible, but yet so erroneous; otherwise the most grievous disappointments will be the consequence. Dazzled and gratified with the spectacle of the Engine, with her carriage and twenty passengers, moving up the plane at a speed hitherto not attained by the swiftest mails, the spectator forgot, or was not aware, that she would have taken *four* carriages, each with its score of passengers, at the *same speed*, on *a level;* or, in more general terms, that the *annual performance* of a Locomotive Engine, on a *level* Railway, would be about four times as great as on an inclined plane, rising one yard in a hundred. I have said *about* four times; for the comparative ratio will depend much on the *weight* of the Engine, the speed of travelling, and the construction of the carriage wheels and axles. The more power you can comprise in the same *weight* of Engine, the greater will be her *comparative* performance on an *inclined plane;* and on the other hand, the greater the improvement in wheels and axles, and the more the *friction* is *diminished*, the greater will be the *comparative* performance on a *level*. Mr. Nicholas Wood, in his book on Railways, estimates the friction of loaded waggons at $\frac{1}{200}$ of the load moved; that is, that one pound weight, suspended over a pulley, would draw 200 lb. on a level Railway. Since Mr. Wood made his experiments, further improvements have been made in the construction of wheels and axles; perhaps to the extent of 25 per cent., leaving the amount of friction on a level Railway $\frac{1}{250}$ of the load moved, or 9 lb. per ton. This ratio, however, allows nothing for the resistance of the air: it supposes both waggons and Railway in very complete order, and the line an absolute and undeviating level. Moreover, experiments on the *friction* of waggons have generally been made on *single* waggons; and there is reason to believe, that the resistance offered by a number of waggons fastened to each other is greater than the proportionate weight would indicate: and this may be accounted for by the separate carriages being *out of square*, with reference to each other, thereby occasioning a straining and lateral friction. On the whole, perhaps, we shall come sufficiently near the truth if we adopt Mr. Wood's ratio of $\frac{1}{200}$ as the amount of resistance to a train of waggons on a level way, under ordinary circumstances of rails and waggons, wind and weather. The inclination of the Whiston plane being 1 in 96, the opposing force of gravity of any load on its ascent will be $\frac{1}{96}$th of the whole weight moved; or if we say $\frac{1}{100}$th part, the resistance by ***gravity*** will be ***double*** the resistance by ***friction.*** It will follow, then, that if a Locomotive Engine, weighing 4 tons 10 cwt. is exactly able to draw after it 30 tons weight on *a level*, at fifteen miles per hour (which I estimate to be the power of an Engine on the " Rocket" principle, with the latest improvements), the same Engine will draw only 7 tons, at the *same speed*, up an *inclined plane* rising one yard in a hundred. This result may be illustrated as follows:—

The load *drawn* on the inclined plane is declared to be.. 7 tons.

Now the *additional* resistance (by *gravity)* is double the resistance by *friction;* then, as the load drawn is 7 tons, the *gravity* of the plane equals the *friction* of ....14 tons.

But the Engine weighs 4 tons 10 cwt., and is opposed by a force of gravity equal to the *friction* of double that weight, or.. 9 tons.

Therefore 7 tons on the *inclined plane* equals the draught of .. } 30 tons on a *level*, at 15 miles per hour.

Or the same result may be brought out by another process, as follows:—The gross weight proposed to be drawn on *a level* is 30 tons, at fifteen miles per hour, on which the friction, estimated at $\frac{1}{200}$, = 336 lb.

hogsheads of sugar or coffee with the celerity of a parcel by the post-coach; and the *warehouseman* in the Metropolis will be supplied with his bales of spring goods, from Manchester, in less time than he has been accustomed to receive his patterns by the flying van.

But we must not confine our views to London, or Liverpool, or Manchester: there can be no question that foreign countries will adopt the Railway communication, as one great step in mechanical improvement and commercial enterprise. France and Germany and America have already their Railways; and the Pasha of Egypt may be expected to follow close on the heels of his brother potentates. The country of the Pyramids, of Memphis, and of Thebes, shall then be celebrated for Railways and Steam Carriages; the land of the proud Mameluke or the wandering Arab, of Sphynxes and Mummies, will become the theatre of mechanical invention, science and the arts. The stately Turk, with his turban and slippers, will quit his couch and his carpet, to mount his Engine of fire and speed, that he may enjoy the delight of modern locomotion. So long is it, since a reward was offered to the inventor of a new pleasure, that some scepticism were excusable as to the possibility of any great and novel excitement. But the Locomotive Engine and Railway were reserved for the present day. From west to east, and from north to south, the mechanical principle, the philosophy of the nineteenth century, will spread and extend itself. The world has received a new impulse To the fortunate few, who are independent of times and circumstances, the present moment is a period of more than ordinary interest; to the world at large, it continues, as it was wont to be, a season of labour and difficulty. Whether the period will ever arrive when a whole community shall enjoy the pleasures and satisfactions to be expected from that happy combination of the powers and capabilities of the human race, which is conceivable, but has hitherto been realized only by the Utopian theorist;—whether we shall ever see united, the energy, activity, and enterprise of a refined and commercial people, with the simplicity and quiet enjoyment of philosophical life, in its most favoured aspects;—whether the period will sometime come, when the fervour of an earnest enthusiasm—religious, moral, social—shall not be inconsistent with the calculations of the merchant, or the speculations of the political economist;—when science and literature, commerce and the arts, and all the stirring influences of man's nature, in the highest state of wealth and civilization, shall be enlisted to promote the improvement and well-being of the whole community;—when, by a happy alchemy, the iron and the golden age shall be amalgamated, and man be allowed to enjoy the benefits of two states of society, hitherto deemed incompatible, or at least separated, in our experience, by intervening centuries, if indeed either counterpart has ever been realised.—These are speculations which we may glance at, for a moment, in passsing, and forget when the vision is gone. But the world and its inhabitants are constantly before us; and here we find no pause or resting place—no period of uninterrupted enjoyment or repose, for the million. The genius of Watt, or Davy, or Stephenson, may improve the state of nations, or the fortunes of individuals, but it affects not the condition of the great mass of the human race: for this consummation we must look to other sciences than chemistry and mechanics; to the tardy overthrow of prejudice, and the slow progress of unpopular truth; to the diffusion of that knowledge which teaches the laws and principles on which depend the moral, physical, and political condition, the subsistence, and well-being of mankind.

Meanwhile, the genius of the age, like a mighty river of the new world, flows onward, full, rapid, and irresistible. The spirit of the times must needs manifest itself in the progress of events, and the movement is too impetuous to be stayed, were it wise to attempt it. Like the "Rocket" of fire and steam, or its prototype of war and desolation—whether the harbinger of peace and the arts, or the Engine of hostile attack and devastation—though it be a futile attempt to oppose so mighty an impulse, it may not be unworthy our ambition, to guide its progress and direct its course.

APPENDIX.

GENERAL ABSTRACT OF EXPENDITURE TO 31ST MAY, 1830.

Advertising Account				£ 332	1	4
Brickmaking Account				9,724	4	4
Bridge Account				99,065	11	9
Charge for Direction				1,911	0	0
Charge for Fencing				10,202	16	5
Cart Establishment				461	6	3
Chat Moss Account				27,719	11	10
Cuttings and Embankments				199,763	8	0
Carrying Department, comprising						
Amount expended in Land and Buildings for Stations and Depots, Warehouses, Offices, &c. at the Liverpool end	£35,538	0	0			
Expended at the Manchester Station	6,159	0	0			
Side Tunnel, being the approach to the Crown-street Station	2,485	0	0			
Gas Light Account, including cost of Pipes, Gasometer, &c.	1,046	0	0			
Engines, Coaches, Machines, &c.	10,991	11	4			
				56,219	11	4
Formation of Road				20,568	15	5
Iron Rail Account				67,912	0	2
Interest Account (balance)				3,629	16	7
Land Account				95,305	8	8
Office Establishment				4,929	8	5
Parliamentary and Law Expenditure				28,465	6	11
Stone Blocks and Sleepers				20,520	14	5
Surveying Account				19,829	8	7
Travelling Expenses				1,423	1	5
Tunnel Account				34,791	4	9
Tunnel Compensation Account				9,977	5	7
Waggon Account				24,185	5	7
Sundry Payments for Timber, Iron, Petty Disbursements, &c. not included in the foregoing Accounts				2,227	17	3
				£739,165	5	0

SCHEDULE OF BRIDGES ON THE

	NAMES OF BRIDGES, *Commencing at the Liverpool end.*	No. of Arches.	Skew or Square built.	Railway *under* or *over* the common road.	Span of the Arch, in feet, on the skew face.		Whether Ashler, Rubble, or Brick Work.
					Ft.	In.	
1	Parks' Bridge	1	Square.	Under.	—		Ashler with brick arch, faced with
2	Old Lane Bridge	1	Square.	Under.	—		Brick-work.
3	Wright's Bridge	1	Square.	Under.	—		Brick-work.
4	Rathbone's Lane Bridge	1	Askew.	Under.	38	0	Ashler with brick arch, faced with
5	Sandown Bridge	1	Square.	Under.	—		Ashler.
6	Mill Lane Archway	1	Askew.	Under.	25	6	Brick-work.
7	Wavertree Nook Bridge	1	Askew.	Under.	38	0	Ashler.
8	Ainsworth's Bridge	1	Square.	Over.	—		Ashler.
9	Case's Bridge, No. 1	1	Square.	Over.	—		Ashler.
10	Ditto, No. 2	1	Square.	Over.	—		Ashler.
11	Childwall Lane Bridge	1	Square.	Over.	—		Brick arch and ashler qu
12	Pilch Lane Bridge	1	Square.	Over.	—		Ditto.
13	Jamieson's Bridge	1	Square.	Over.	—		Ditto.
14	Lord Derby's Bridge	1	Square.	Over.	—		Ditto.
15	Baron's Bridge	1	Square.	Over.	—		Ditto.
16	Ball's Bridge	1	Square.	Over.	—		Ditto.
17	Huyton Hey Bridge	1	Square.	Over.	—		Ditto.
18	Seel's Bridge	1	Square.	Over.	—		Rubble, with ashler qu
19	Lee's Bridge, No. 2	1	Square.	Over.	—		Brick arch and ashler qu
20	Ditto, No. 1	1	Square.	Over.	—		Ditto.
21	Whiston Bridge, No. 1	1	Square.	Under.	—		Ditto.
22	Ditto, No. 2	1	Askew.	Under.	47	0	Ashler with brick arch, faced with
23	Makin's Occupation Bridge	—	Unfshd.	—	—		Timber on stone pier
24	Cumber Lane Bridge	1	Square.	Under.	—		Ashler.
25	Stone Lane Bridge	1	Square.	Under.	—		Wood with stone pier
26	Spring Lane Bridge	1	Square.	Under.	—		Ashler with brick arch, faced with
27	Rainhill Bridge	1	Askew.	Under.	54	0	Ashler.
28	Bourne's Tunnel	1	Askew.	Over.	14	0	Ashler and rubble.
29	Marshall's Cross Bridge	1	Square.	Under.	—		Ashler.
30	Sutton Bridge	1	Square.	Under.	—		Ashler.
31	Sankey Viaduct	9	Square.	Over.	—		Brick with stone face, quoins & par
32	Legh's Cattle Archway	1	Square.	Over.	—		Brick-work.
33	Sandy Main's Bridge	1	Askew.	Over.	15	6	Brick-work.
34	Newton Bridge	4	Square.	Over.	—		Brick-work, with stone fa
35	Parkside Bridge	1	Askew.	Under.	32	6	Brick-work.
36	Lockingstump Lane Bridge	1	Square.	Under.	—		Brick-work.
37	Kenyon Tunnel	1	Square.	Under.	—		Brick-work.
38	Hardman's Bridge	1	Square.	Under.	—		Brick-work.
39	Newton's Bridge	1	Square.	Under.	—		Brick-work.
40	Broseley Bridge	1	Square.	Under.	—		Brick-work.
41	Withington's Bridge	1	Square.	Over.	—		Brick-work.
42	Duckinfield's Bridge	1	Square.	Over.	—		Brick-work.
43	Bury Lane Bridge	1	Square.	Over.	—		Brick, with stone quoi
44	Glazebrook Bridge	1	Square.	Ov.Brook	—		Brick, with stone quoins&stone pil
45	Hodgkinson's Cattle Bridge	1	Square.	Over.	—		Brick.
46	Chat Moss (Frame) Bridge	1	Square.	Over.	—		Brick and timber.
47	Legh's Brick Arch	1	Square.	Over.	—		Brick.
48	Worsley Brook, Great Culvert	1	Square.	Ov.Brook	—		Brick.
49	Trafford's Bridge	1	Square.	Over.	—		Brick.
50	Sandy Lane Bridge	1	Square.	Over.	—		Brick and stone quoin
51	Winton Skew Bridge	1	Askew.	Over.	31	0	Brick and stone pilaste
52	Canal (Duke's) Bridge	2	Square.	Over.	—		Dressed ashler.
53	Monks' Hall Bridge	1	Square.	Under.	—		Brick.
54	Eccles Bridge	1	Sq. & Askew	Under.	34	0	Brick and stone quoin
55	Whitaker's Mill Dam	......	....	....	......		Brick-work and Masonr
56	Stothard's Occupation Bridge	1	Square.	Under.	—		Brick.
57	Gore Booth's Bridge	1	Square.	Under.	—		Brick.
58	Cross Lane Bridge	1	Askew.	Under.	30	3	Brick and stone quoins to arch
59	Jones's Bridges—No. 1	1	Askew.	Under.	30	4	Brick.
60	No. 2	1	Askew.	Under.	30	3	Brick.
61	No. 3	1	Askew.	Under.	30	3	Brick and stone quoin
62	Oldfield Lane Bridge	1	Askew.	Under.	33	0	Brick and stone quoin
63	Irwell Bridge	2	Askew.	Ov. River	65	0	Ashler.
	Sundry Culverts, Foot Bridges, and compensation in lieu of Occupation Bridges						

LIVERPOOL AND MANCHESTER RAILWAY.

	Description of String Course and Coping.	Abutments, whether Rock, Masonry, or Brick Work.	Width of way, in feet, between Parapets *over* Arch.		Width of way, in feet, between Side Walls *under* Arch.		Height under the centre of the Arch, from Railway or common road, in feet.		Slope of common road *over* the Railway.	Slope of common road *under* the Railway.	Number of feet common road is *raised*.		Number of feet common road is *sunk*.		COST.		
			Ft.	In.	Ft.	In.	Ft.	In.			Ft.	In.	Ft.	In.	£.	*S.*	*D.*
1	Stone.	Masonry.	28	0	30	0	26	9	Level.	—	—		—		741	5	9
2	Stone.	Brick.	12	0	30	0	18	0	Level.	—	—		Unfshd.		156	10	0
3	Stone.	Brick.	15	0	30	0	18	0	Level.	—	—		—		184	5	6
4	Stone.	Masonry.	23	6	30	0	24	3	Level.	—	—		Unfshd.		973	14	2
5	Stone.	Masonry.	15	8	40	0	40	6	Level.	—	—		—		765	13	1
6	None.	Rock.	60	0	25	0	35	0	Level.	—	—		—		91	3	11
7	Stone.	Rock.	20	0	37	6	18	0	1 in 20	—	3	0	—		274	9	4
8	Stone.	Masonry.	34	6	12	0	13	6	—	Level.	—		—		418	5	10
9	Stone.	Masonry.	34	6	12	0	16	0	—	Level.	—		—		418	0	2
10	Stone.	Masonry.	34	6	12	0	16	0	—	Level.	—		—		493	0	3
11	Stone.	Masonry.	66	6	14	0	16	0	—	Level.	—		—		346	12	1
12	Stone.	Masonry.	34	6	16	0	16	0	—	1 in 30	—		5	6	270	1	0
13	Stone.	Masonry.	34	6	12	0	18	0	—	Level.	—		—		202	7	0
14	Stone.	Masonry.	34	6	12	0	20	0	—	Level.	—		—		241	16	1
15	Stone.	Masonry.	34	6	12	0	16	0	—	Level.	—		—		240	9	11
16	Stone.	Masonry.	34	6	12	0	19	0	—	Level.	—		—		204	5	5
17	Stone.	Masonry.	34	6	12	0	12	4	—	Level.	—		—		302	3	2
18	Stone.	Masonry.	34	6	12	0	14	0	—	1 in 30	—		1	6	215	0	3
19	Stone.	Masonry.	34	6	12	0	14	10	—	Level.	—		—		215	8	10
20	Stone.	Masonry.	34	6	12	0	21	10	—	Level.	—		—		282	0	9
21	Stone.	Masonry.	47	6	22	0	18	0	1 in 13	—	14	0	—		960	5	0
22	Stone.	Masonry.	24	0	30	0	18	0	1 in 20	—	15	0	—		1174	0	1
23	—	—	—		30	0	—		—	—	—		—		74	15	2
24	Stone.	Masonry.	16	0	30	0	18	0	1 in 20	—	12	0	—		536	13	0
25	Stone.	Masonry.	9	0	45	0	18	0	Level.	—	—		—		193	15	3
26	Stone.	Masonry.	16	0	30	0	18	0	1 in 30	—	8	0	—		418	19	8
27	Stone.	Masonry.	30	0	30	0	18	0	1 in 26	—	12	0	—		3735	6	7
28	Stone.	Masonry.	104	0	7	0	7	0	—	—	—		—		165	5	9
29	Stone.	Masonry.	24	0	30	0	18	0	1 in 20	—	5	0	—		864	13	10
30	Stone.	Masonry.	26	6	30	0	23	0	Level.	—	—		—		470	8	9
31	Stone.	Brick-work.	25	0	50	0	60	to Canal	—	—	—		—		45,208	18	6
32	None.	Brick.	None.		12	0	6	0	—	—	—		—		257	18	5
33	Stone.	Brick.	35	0	12	0	15	0	—	—	—		—		429	0	1
34	Stone.	Brick.	25	0	30	0	27	0	—	—	—		—		5340	12	5
35	Stone.	Rock.	20	0	30	0	18	6	1 in 18.	—	6	0	—		316	19	6
36	Stone.	Brick.	20	0	30	0	18	0	Level.	—	—		—		491	14	9
37	Stone.	Brick.	—		30	0	19	0	Level.	—	—		—		1703	19	1
38	Stone.	Brick.	12	0	30	0	20	0	1 in 9	—	—		3	6	434	7	9
39	Stone.	Brick.	12	0	30	0	18	0	1 in 12	—	7	0	—		369	12	2
40	Stone.	Brick.	20	0	30	0	18	0	1 in 18	—	7	0	—		663	4	10
41	Stone.	Brick.	35	0	12	0	14	0	—	Level.	—		—		419	15	4
42	Stone.	Brick.	35	0	12	0	14	0	—	Level.	—		—		323	10	3
43	Stone.	Brick.	35	0	16	0	16	0	—	1 in 20	—		3	0	621	1	7
44	Stone.	Brick.	35	0	30	0	30	ab. Riv.	—	—	—		—		1758	8	6
45	Stone.	Brick.	35	0	9	0	10	0	—	—	—		Unfshd.		13	9	0
46	Stone.	Brick.	25	0	12	0	13	0	—	—	—		—		466	19	6
47	Stone.	Brick.	25	0	16	0	16	0	—	Level.	—		—		513	9	6
48	Stone.	Brick.	125	0	13	0	13	to Wat.	—	—	—		—		1598	5	8
49	Stone.	Brick.	69	0	12	0	13	0	—	Level.	—		—		589	6	0
50	Stone.	Brick.	25	0	16	0	21	0	—	Level.	—		—		1098	18	4
51	Stone.	Masonry.	25	0	22	0	20	0	—	Level.	—		—		1725	10	5
52	Stone.	Masonry.	25	0	25	0	12	to Wat.	—	Level.	—		—		1158	8	11
53	Stone.	Red Rock.	36	0	30	0	18	0	1 in 18	—	6	0	—		453	19	11
54	Stone.	Red Rock.	48	0	30	0	18	0	1 i 24	—	6	0	—		954	0	1
55	....	....	....		....		....		....	....	....		....		631	10	2
56	Stone.	Brick.	12	0	30	0	16	0	1 in 14	—	5	0	Unfshd.		31	19	0
57	Stone.	Brick.	18	8	30	0	18	0	1 in 18	—	5	0	—		417	13	7
58	Stone.	Brick.	48	0	30	0	18	0	1 in 30	—	6	0			801	12	3
59	Stone.	Brick.	42	0	30	0	18	0	1 in 20	—	6	0	Unfinished				
60	Stone.	Brick.	42	0	30	0	18	0	—	—	6	0			559	14	5
61	Stone.	Brick.	48	0	30	0	18	0	1 in 20	—	6	0					
62	Stone.	Brick.	48	0	30	0	18	0	1 in 13	—	7	0			988	15	11
63	Stone.	Masonry.	53	0	63	0	30	to Riv.	—	—	—				8795	4	4
	....	....	....		....		....		....	....	....		....		4296	16	0
														£	99,065	11	9

OBSERVATIONS.

Brickmaking Accounts.—The greater part of these Bricks are fast using in the building of the Manchester Warehouses, Offices, &c. and some in completing the Bridges at each end of the line.

Bridges.—The foregoing description of the several Bridges in a tabular form, I have thought would not be uninteresting, as affording a popular view of the kind of structures that may be expected to occur in similar undertakings. It will be seen that several of the Bridges are still unfinished, though fast approaching their completion —for this purpose a fund is reserved, as per the estimate below.

Chat Moss.—Under this head is comprised the earth-work from Bury-lane Bridge to Legh's Occupation Bridge, on the east border of the Moss, a distance of 4¾ miles. The Embankments in this space consist of about 277,000 cubic yards of moss earth, in the formation of which about 677,000 cubic yards of raw moss have been used; the difference in measurement being occasioned by the squeezing out of the superabundant water, and consequent consolidation of the moss. The expenditure on this district has been less than the average expenditure of the rest of the line.

Cuttings and Embankments.—Under this head is comprised the earth-work on the whole line, exclusive of the Chat Moss district. The Cuttings somewhat exceed the Embankings: the surplus is principally deposited along the border of the great Kenyon Cutting. The Excavations consist of about 722,000 cubic yards of rock and shale (including some side cuttings at Eccles, to expedite and improve the consistency of the Barton Embankment), and about 2,006,000 cubic yards of marle, earth and sand. This aggregate mass has been removed to various distances, from a few furlongs to between three and four miles; and no inconsiderable portion of it has been hoisted up by machinery, from a depth of 30 to 50 feet, to be deposited on the surface above, either to remain in permanent spoil banks, as at Kenyon, or to be afterwards carried to the next embankment, as at the deep rock cutting through Olive Mount; the process in this latter case being rendered expedient from considerations of increased expedition. Where land for the deposit of spoil banks has been purchased, the cost of the land forms part of the expenditure under this head, and a good deal of substantial and lofty walling in the deep cuttings is also included. The unavoidable expense of pumping out the water from the several cuttings on the line during a wet season, was adverted to in the text.

Formation of the Permanent Road.—This consists of what is termed ballasting the road—that is, depositing a layer of broken rock and sand, about two feet thick, viz. one foot *below* the blocks, and one foot distributed *between* them, serving to keep them firm in their places. Spikeing down the iron chairs to the blocks or sleepers, fastening the rails to the chairs with iron keys, and adjusting the rail-way to the exact width and curve and level, come under this head of expenditure.

Iron Rail Account.—This expenditure comprises the following items:—

Rails for a double way from Liverpool to Manchester, with occasional lines of communication, and additional side lines at the different Depots, being about 35 miles of double way, = 3847 tons, at prices averaging something less than £12. 10s. per ton	£48,000	0	0
Cast-iron Chairs, 1428 tons, at an average of £10. 10s...	15,000	0	0
Cost of Spikes and Keys, to fasten the Chairs to the Blocks and the Rails to the Chair........	3,830	0	0
Cost of Oak Plugs for the Blocks	615	0	0
Sundry Freights, Cartages, &c. &c.	467	0	2
	£67,912	0	2

Land.—This is a heavy item of expenditure. The price of land in the vicinity of large towns is usually high; and the outlay was further enhanced by numerous claims for compensation, owing to the prejudice which a few years since existed against Railways, and especially against what now appears their peculiar recommendation—the Locomotive Engine. A great change has taken place in this respect. At the close of 1828 the charge under this head was nearly £102,000., but a portion of this amount being for the Depots, has been transferred to the Carrying Department.

Office Establishment.—This comprises the salaries of Treasurer and Clerks, Office Rent, Stationary, Printing, &c. since October, 1824.

Stone Blocks and Sleepers.—Out of the 31 miles, about 18 are laid with Stone Blocks, and 13 with Wood Sleepers, oak or larch; these latter being laid principally across the Embankments, and across the two districts of moss. A considerable quantity of Wood Sleepers have been destroyed, unavoidably, in the progress of the work.

Surveying Account.—This comprises the cost of Surveys, Plans, &c. for the two applications to Parliament, in 1825 and 1826; also the salaries of the Engineer, and principal Assistants, Stationary, &c. from the commencement of the undertaking.

Travelling Expenses.—This includes the cost of sundry journeys and deputations to London, Darlington, Newcastle, &c. since 1824: also the cost of journeys of inspection on the line of Railway during the progress of the works.

Tunnel Compensation Account.—This consists of compensation paid to parties under whose premises the Liverpool Tunnel is excavated, for damage, either real or supposed; and further, of loss sustained on the re-sale of sundry houses and lands which the Company were required to purchase. There will be a credit to this account for premises re-sold to the extent of about £2500.

Waggon Account.—This expenditure is principally for waggons used in the progress of the work. There will be a credit to this account from the re-sale of such waggons as cannot conveniently be adapted to the future purposes of the Railway, and by a transfer of the remainder to the carrying department, at their estimated value.

It will be observed that the statement of expenditure is up to the 31st of May, 1830. The Railway, however, will require a further outlay to render it complete, though the Locomotive Engine has passed over every foot of ground from Liverpool to Salford. The slopes of the Cuttings want dressing, and several of them want protecting with foot walls. The permanent road-way is not quite finished, and some portions that have been laid down require adjusting and re-levelling. The fencing also in portions of the line will be incomplete for some time.

The Directors, in their Report dated 25th March last, estimated the total expenditure, including Warehouses, Machinery and Carriages, at £820,000., which may be apportioned as follows:—

Expenditure, as above, in actual payments, to 31st May	£739,165	5	0
Outstanding engagements to the same date	7,500	0	0
For Walling the Slopes in sundry places, and completing permanent road	6,750	0	0
For completing the Bridges, including the Irwell, £6000, and Parapets of the Sankey Viaduct £1400, and compensation in lieu of bridges	9,500	0	0
Additional Engines, Waggons and Machinery, part under contract for delivery	17,000	0	0
Completing Stations, Wharfs, Warehouses, Offices, &c.	25,000	0	0
Fencing at sundry places	3,000	0	0
Contingencies	12,084	15	0
	£820,000	0	0

The public opening of the Railway is a subject of interest and inquiry. It is some time since coal for the Company's purposes was conveyed from the Elton Head Collieries, in Sutton, to the Crown-street Station, in Liverpool; and on the 14th of the present month (June), an experiment was made which may be regarded as a preliminary measure to a general opening, well calculated to exhibit the peculiar character of Railway conveyance, and to put to the test the capabilities of the Locomotive Engine. On this occasion the Directors, in two of their carriages (the one a close glass coach, the other an open carriage) proceeded in a journey of inspection from Liverpool to Manchester and back. The Arrow Locomotive, one of the improved Engines on the Rocket principle, was the moving power. The gross weight drawn was about 33 tons, consisting as follows:—

Stone in seven Waggons	20 tons.
Weight of Waggons	7 „
Engine-Tender and six persons	3 „
Two Carriages and 20 persons	3 „
	33 tons.

With this load she travelled from the Engine House, Liverpool, to Oldfield-lane Bridge, Salford, Manchester, the distance being about 29 miles, in two hours and 25 minutes, including two stoppages to take in water. Up the Whiston inclined plane she was assisted by the Dart, an Engine of similar construction and power, and the first quarter of a mile of the ascent was accomplished at a speed of 17 miles per hour, which however decreased to about 4 miles per hour before the summit was gained, the mile and a half being accomplished in 12 minutes, the average speed, therefore, being 7½ miles per hour. At the top of the ascent, the Dart was unyoked, and the Arrow proceeded with her cargo along the straight and level plane at Rainhill at the rate of 16 miles per hour. On the return from Manchester the Engine-Tender and the two Carriages with passengers, constituted the whole load drawn. The first 9¼ miles from Oldfield-lane Bridge to Glazebrook Bridge, including the Chat Moss district, were accomplished at a speed averaging from 19 to 20 miles per hour. The whole distance was accomplished in 1 hour and 46 minutes, including stoppages, the speed generally varying from 18 to 25 miles and upwards per hour, and the Engine not working to her full power, a great portion of the way. The speed up the Sutton inclined plane, (without any assistant Engine,) averaged more than 15 miles per hour. The day was wet, and the rails, in places, very dirty; the whole performance therefore, took place under circumstances by no means favourable; but the result was highly satisfactory.

It will now be in the discretion of the Directors to name the day when they shall consider the Railway in that state of completeness which may render expedient the public conveyance of passengers or merchandise, either the whole distance, or along part of the line in the first instance. It may be sufficient to refer the date of the opening of the Liverpool and Manchester Railway to the summer of 1830.

Liverpool, June, 1830.

BODLEIAN

FINIS.

PRINTED BY WALES AND BAINES, CASTLE-STREET.

A.214
m/px/-